NASA SP-4103

MODEL RESEARCH

The National Advisory Committee for Aeronautics 1915–1958

Volume 2

Alex Roland

The NASA History Series

Scientific and Technical Information Branch 1985
National Aeronautics and Space Administration
Washington, DC

NASA maintains an internal history program for two principal reasons: (1) Sponsorship of research in NASA-related history is one way in which NASA responds to the provision of the National Aeronautics and Space Act of 1958 that requires NASA to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." (2) Thoughtful study of NASA history can help agency managers accomplish the missions assigned to the agency. Understanding NASA's past aids in understanding its present situation and illuminates possible future directions.

One advantage of working in contemporary history is access to participants. During the research phase, the authors conducted numerous interviews. Subsequently they submitted parts of the manuscript to persons who had participated in or closely observed the events described. Readers were asked to point out errors of fact and questionable interpretations and to provide supporting evidence. The authors then made such changes as they believed justified. The opinions and conclusions set forth in this book are those of the authors; no official of the agency necessarily endorses those opinions or conclusions.

Roland, Alex, 1944—
Model research.

—

(The NASA history series) (NASA SP; 4103)
Bibliography: p. 305
Includes index.
1. United States. National Advisory Committee for Aeronautics—History. I. Title. II. Series. III. Series: NASA SP; 4103.
TL521.612.R58 1985 352.0085'6 83-14137

Contents

Illustrations

Page

Vol. I

Vol. II

Appendix A
Legislation

Part I of this appendix contains the major pieces of legislation that affected the NACA. The public law number, Congress, session, date passed, and citation in the *United States Statutes at Large* are given for each act. Some of the laws are reprinted in full; for others, only extracts of the section pertaining to the NACA are provided.

The NACA's organic legislation stated "That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President." Part II of this appendix contains the various forms of the rules and regulations under which the Committee operated over the years, from the first set submitted to President Wilson on 23 April 1915 to the final set approved by President Truman on 3 May 1949.

The organic act of the NACA was interpreted to be its authorizing legislation, so its budget was not authorized annually. The Committee's appropriation legislation is cited in appendix C, along with the handful of authorization acts passed for the NACA in the 1950s.

The laws printed here are:

Naval Appropriations Act, 1916 (3 March 1915)
Sundry Civil Act, 1919 (1 July 1918)
Sundry Civil Act, 1927 (22 April 1926)
"Air Commerce Act of 1926" (20 May 1926)
Army Air Corps Act (2 July 1926)
Amendment of Army Air Corps Act (3 March 1927)
NACA Membership Act (2 March 1929)
"Civil Aeronautics Act of 1938" (23 June 1938)
NACA Overtime Pay Act (10 February 1942)
"War Overtime Pay Act of 1943" (7 May 1943)
"National Security Act of 1947" (26 July 1947)
"Independent Offices Appropriation Act, 1948" (30 July 1947)
"Armed Services Procurement Act of 1947" (19 February 1948)
"Independent Offices Appropriation Act, 1949" (20 April 1948)
NACA Membership Act (25 May 1948)
NACA Professional Pay Act (13 July 1949)
"Unitary Wind Tunnel Plan Act of 1949" (27 October 1949)
NACA Graduate School Attendance Act (11 April 1950)
Authorization Act (8 August 1950)
"Independent Offices Appropriation Act, 1951" (6 September 1950)
NACA Membership Act (3 June 1954)
"Federal Executive Pay Act of 1956" (31 July 1956)
"National Aeronautics and Space Act of 1958" (29 July 1958)

The rules and regulations printed here are:

George P. Scriven to the president, 23 April 1915, with enclosure
C. D. Walcott to the president, 28 April 1915

Public Law 271, 63d Cong., 3d sess., passed 3 March 1915 (38 Stat. 930)

An Act Making appropriations for the naval service for the fiscal year ending June thirtieth, nineteen hundred and sixteen, and for other purposes.

Two paragraphs in this act created the National Advisory Committee for Aeronautics. Though almost lost amidst the 25 pages of text in the *United States Statutes at Large,* these few words formed the organic act by which the NACA was to operate for 43 years. The NACA section reads in full:

> An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences: Provided, That the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: Provided further, That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories: And provided further, That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.
>
> That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and necessary expenses of members

of the committee in going to, returning from, and while attending meetings of the committee: Provided, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.

Public Law 181, 65th Cong., 2d sess., passed 1 July 1918 (40 Stat. 650)

An Act Making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred and nineteen, and for other purposes.

Provision was made in the NACA annual appropriation for 1919 "That the Secretary of War is authorized and directed to furnish office space to the National Advisory Committee for Aeronautics in governmental building occupied by the Signal Corps." The army did not always comply with this provision, but it was not formally repealed until 1948.

Public Law 141, 69th Cong., 1st sess., passed 22 April 1926 (44 Stat. 314)

An Act Making appropriations for the Executive Office and sundry independent executive bureaus, boards, commissions, and offices for the fiscal year ending June 30, 1927, and for other purposes.

The NACA's annual appropriations for fiscal year 1927 provided that the Committee's laboratory at Hampton, Virginia, should be officially "known as the Langley Memorial Aeronautical Laboratory." It was renamed in 1948.

Public Law 254, 69th Cong., 1st sess., passed 20 May 1926 (44 Stat. 568)

Air Commerce Act of 1926

The following paragraphs assigned to the secretary of commerce functions previously performed unofficially by the NACA:

Sec. 2. PROMOTION OF AIR COMMERCE.—It shall be the duty of the Secretary of Commerce to foster air commerce in accordance with the provisions of this Act, and for such purpose—

* * *

(b) To make recommendations to the Secretary of Agriculture as to necessary meteorological service.

(c) To study the possibilities for the development of air commerce and the aeronautical industry and trade in the United States and to collect and disseminate information relative thereto and also as regards the existing state of the art.

(d) To advise with the Bureau of Standards and other agencies in the executive branch of the Government in carrying forward such research and development work as tends to create improved air navigation facilities. The Secretary of Commerce is authorized to transfer funds available for carrying out the purposes of this subdivision to any such agency for carrying forward such research and development work in cooperation with the Department of Commerce.

(e) To investigate, record, and make public the causes of accidents in civil air navigation in the United States.

(f) To exchange with foreign governments through existing governmental channels information pertaining to civil air navigation.

Public Law 446, 69th Cong., 1st sess., passed 2 July 1926 (44 Stat. 788)

An Act To provide more effectively for the national defense by increasing the efficiency of the Air Corps of the Army of the United States, and for other purposes.

This act created the Army Air Corps. Section 10 (r) applied to the NACA.

A board to be known as the patents and design board is hereby created, the three members of which shall be an Assistant Secretary of War, an Assistant Secretary of the Navy, and an Assistant Secretary of Commerce. To this board any individual, firm, or corporation may submit a design for aircraft, aircraft parts, or aeronautical accessories, and whether patented or unpatentable, the said board upon the recommendation of the National Advisory Committee for Aeronautics shall determine whether the use of such designs by the Government is desirable or necessary, and evaluate the designs so submitted and fix the worth to the United States of said design, not to exceed $75,000. The said designer, individual, firm, or corporation may then be offered the sum fixed by the board for the ownership or a nonexclusive right to the use of the design in aircraft, aircraft parts, or aeronautical accessories and upon the acceptance thereof shall execute complete assignment or nonexclusive license to the United States: Provided, That no sum in excess of $75,000 shall be paid for any one design.

Public Law 748, 69th Cong., 2d sess., passed 3 March 1927 (44 Stat. 1380)

An Act To amend the Act entitled 'An Act To provide more effectively for the national defense by increasing the efficiency of the Air Corps of the Army of the United States, and for other purposes,' approved July 2, 1926.

Section 10 (r) of the Army Air Corps of 1926 implied that the patents and design board could act only in accordance with the recommendations of the NACA, and that the NACA was to determine whether designs were desirable or necessary to the United States, This act amended the second sentence of that section so as to compose three sentences to read as follows:

Any individual, firm, or corporation may submit to the board for its action any design, whether patented or unpatented, for aircraft, aircraft parts, or aeronautical accessories. The board shall refer any design so submitted to the National Advisory Committee for Aeronautics for its recommendation. If and when the committee makes a favorable recommendation to the board in respect of the design, the board shall then proceed to determine whether the use of the design by the Government is desirable or necessary and evaluate the design and fix its worth to the United States in an amount not to exceed $75,000.

Public Law 908, 70th Cong., 2d sess., passed 2 March 1929 (45 Stat. 1451)

An Act To increase the membership of the National Advisory Committee for Aeronautics.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the membership of the National Advisory Committee for Aeronautics is hereby increased from twelve members to fifteen members: Provided, That the three additional members to be appointed by the President shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences, and shall serve as such without compensation.

Public Law 706, 75th Cong., 3d sess., passed 23 June 1938 (52 Stat. 1027)

Civil Aeronautics Act of 1938

This act established the Civil Aeronautics Authority and the Air Safety Board and entirely rewrote the regulations governing civil aviation in the United States. Two of its provisions applied to the NACA:

Section 1105. ". . . Nothing contained in this Act shall be construed to authorize the duplication of the laboratory research facilities of any existing governmental agency."

Section 1107. (e) "The ninth paragraph of the Act approved March 3, 1915 (38 Stat. 930), as amended by the Act of March 2, 1929 (45 Stat. 1451; U.S.C., 1934 ed., title 50, sec. 151), is further amended by inserting after the words "naval aeronautics;" in that paragraph the following: "two members from the Civil Aeronautics Authority;", by striking out the word "eight" in that paragraph and inserting in lieu thereof the word "six", and by striking out the colon after the words "allied sciences" and inserting in lieu thereof a period and the following: "The members of the National Advisory

Committee for Aeronautics, not representing governmental agencies, in office on the date of enactment of the Civil Aeronautics Act of 1938, shall continue to serve as members of the committee until the effective date of expiration of the terms of the members whom they succeed, except that any such successor, appointed to fill a vacancy occurring prior to the expiration of a term, shall be appointed only for the unexpired term of the member whom he succeeds:"

Public Law 450, 77th Cong., 2d sess., passed 10 February 1942 (56 Stat. 88)

An Act Authorizing overtime pay for certain employees of the National Advisory Committee for Aeronautics.

> Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That compensation for employment in excess of forty hours in any administrative workweek computed at a rate of one and one-half times the regular rate is hereby authorized to be paid hereafter, under such regulations as the President may prescribe, to those employees in the field service of the National Advisory Committee for Aeronautics whose overtime services are essential to the national defense program and whose duties are determined by the President to be comparable to the duties of those employees of the War Department, the Navy Department, and the Coast Guard, for whom overtime compensation is authorized under existing law and regulations: Provided, That in determining the overtime compensation of per annum employees the base pay for one day shall be considered to be one three-hundred-and-sixtieth of the respective per annum salaries.
>
> Sec. 2. The provisions of this Act shall be effective during the national emergency declared by the President on September 8, 1939, to exist, and shall terminate June 30, 1943, unless the Congress shall otherwise provide.

Public Law 49, 78th Cong., 1st sess., passed 7 May 1943 (57 Stat. 77)

War Overtime Pay Act of 1943

This act established uniform overtime compensation for employees of the federal government and repealed Public Law 450 (77th Cong., 2d sess.) passed in 1942 to authorize overtime for NACA employees.

Public Law 253, 80th Cong., 1st sess., passed 26 July 1947 (61 Stat. 501)

National Security Act of 1947

This act created a National Military Establishment with three military departments under a Secretary of Defense. Technically, the only section affecting the NACA was section 205 (a):

> The Department of War shall hereafter be designated the Department of the Army, and the title of the Secretary of War shall be changed to Secretary of the Army. Changes shall be made in the titles of other officers and activities of the Department of the Army as the Secretary of the Army may determine.

This was a change in name but not substance as far as the NACA was concerned.

Public Law 269, 80th Cong., 1st sess., passed 30 July 1947 (61 Stat. 600)

Independent Offices Appropriation Act, 1948

This act provided "That aircraft and parts, equipment, and supplies may be transferred to the Committee by the Army and Navy without reimbursement."

Public Law 413, 80th Cong., 2d sess., passed 19 February 1948 (62 Stat. 21)

Armed Services Procurement Act of 1947

This act established procedures and regulations "applicable to all purchases and contracts for supplies or services made by the Department of the Army, the Department of the Navy, the Department of the Air Force, the United States Coast Guard, and the National Advisory Committee for Aeronautics."

Public Law 491, 80th Cong., 2d sess., passed 20 April 1948 (62 Stat. 188)

Independent Offices Appropriations Act, 1949

This act provided "That aircraft and parts, equipment, and supplies may be transferred to the Committee by the Air Force, Army, and Navy without reimbursement," adding the air force to the provision made for the army and navy in the previous year's appropriations act (passed 30 July 1948).

Public Law 549, 80th Cong., 2d sess., passed 25 May 1948 (62 Stat. 266)

An Act To promote the national defense by increasing the membership of the National Advisory Committee for Aeronautics and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the eighth paragraph following the caption "Pay, miscellaneous" in the Act entitled "An Act making appropriations for the naval service for the fiscal year ending June thirtieth, nineteen hundred and sixteen, and for other purposes," approved March 3, 1915 (38 Stat. 930; U.S.C., title 49, sec. 241), as amended, is hereby amended to read as follows:

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

"(a) There is hereby established a National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee') to be composed of not more than seventeen members appointed by the President. Members shall serve as such without compensation, and shall include two representatives of the Department of the Air Force; two representatives of the Department of the Navy, from the office in charge of naval aeronautics; two representatives of the Civil Aeronautics Authority; one representative of the Smithsonian Institution; one representative of the United States Weather Bureau; one representative of the National Bureau of Standards; the chairman of the Research and Development Board of the National Military Establishment; and not more than seven other members selected from persons acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences. Unless otherwise provided by law, each member not representing a government department or agency shall be appointed for a term of five years from the date of the expiration of the term of the member whom he succeeds, except that any member appointed to fill a vacancy occurring prior to the expiration of a term shall be appointed for the unexpired term of the member whom he succeeds.

"(b) Under such rules and regulations as shall be formulated by the Committee, with the approval of the President, for the conduct of its work, it shall be the duty of the Committee (1) to supervise and direct the scientific study of the problems of flight with a view to their practical solution, (2) to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions, and (3) to direct and conduct research and experiment in aeronautics in the Langley Aeronautical Laboratory, the Ames Aeronautical Laboratory, the Flight Propulsion Research Laboratory, and in such other laboratory or laboratories as may, in whole or in part, be placed under the direction of the Committee.

"(c) An annual report to the Congress shall be submitted by the Committee through the President, including an itemized statement of expenditures."

Sec. 2. Each member of the National Advisory Committee for Aeronautics not representing a government department or agency who may be appointed initially to fill any vacancy created by the increase in the membership of the Committee authorized by the amendment made by the first section of this Act shall serve under such appointment for a term expiring December 1, 1950.

Sec. 3. The following parts of Acts are hereby repealed:

(a) That portion of the ninth paragraph following the caption "Pay, miscellaneous", in the Act entitled "An Act making appropriations for the naval service for the fiscal year ending June thirtieth, nineteen hundred and sixteen, and for other purposes", approved March 3, 1915 (38 Stat. 930; U.S.C., title 49, sec. 243), which reads as follows: ": Provided, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures".

(b) That portion of the paragraph following the caption "National Advisory Committee for Aeronautics", in the Act entitled "An Act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred and nineteen, and for other purposes", approved July 1, 1918 (40 Stat. 650; U.S.C., title 49, sec. 242), which reads as follows: "Provided, That the Secretary of War is authorized and directed to furnish office space to the National Advisory Committee for Aeronautics in governmental buildings occupied by the Signal Corps".

(c) The portion of the first paragraph following the caption "National Advisory Committee for Aeronautics", in the Act entitled "An Act making appropriations for the Executive Office and sundry independent executive bureaus, boards, commissions, and offices for the fiscal year ending June 30, 1927, and for other purposes", approved April 22, 1926 (44 Stat. 314; U.S.C., title 49, sec. 244), which reads as follows: ", hereafter to be known as the Langley Memorial Aeronautical Laboratory".

Public Law 167, 81st Cong., 1st sess., passed 13 July 1949 (63 Stat. 410)

An Act To amend the Act of August 1, 1947, as amended, to authorize the creation of ten professional and scientific positions in the headquarters and research stations of the National Advisory Committee for Aeronautics.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the first section of the Act entitled "An Act To authorize the creation of additional positions in the professional and scientific service in the War and Navy Departments", approved August 1, 1947, as amended, is hereby amended to read as follows:

"That (a) the Secretary of the Army, the Secretary of the Navy, and the Secretary of the Air Force are respectively authorized to establish and fix the compensation for, within their respective departments, not more than thirteen positions each, and the Secretary of Defense is authorized to establish and fix the compensation for not more than six positions, each such position being established to effectuate those research and development functions, relating to the national defense, military and naval medicine, and any and all other activities of the National Military Establishment which requires the services of specially qualified scientific or professional personnel.

"(b) The Chairman of the National Advisory Committee for Aeronautics is authorized to establish and fix the compensation for, in the headquarters and research stations of the National Advisory Committee for Aeronautics, not to exceed ten positions in the professional and scientific service, each such position being established in order to enable the National Advisory Committee for Aeronautics to secure and retain the services of specially qualified personnel necessary in the discharge of the duty of the committee to supervise and direct the scientific study of the problems of flight with a view to their practical solution.

"(c) The rates of compensation for positions established pursuant to the provisions of this Act shall not be less than $10,000 per annum nor more than $15,000 per annum and shall be subject to the approval of the Civil Service Commission."

Sec. 2. Section 3 of such Act of August 1, 1947, as amended, is hereby amended to read as follows:

"Sec. 3. The Secretary of Defense and the Chairman of the National Advisory Committee for Aeronautics shall submit to the Congress, not later than December 31 of each year, a report setting forth the number of positions established pursuant to this Act in the National Military Establishment and in the headquarters and research stations of the National Advisory Committee for Aeronautics, respectively, during that calendar year, and the name, rate of compensation, and description of the qualifications of each incumbent, together with a statement of the functions performed by each. In any instance where the Secretary or the Chairman, respectively, may consider full public report on these items detrimental to the national security, he is authorized to omit such items from his annual report and, in lieu thereof, to present such information in executive sessions of such committees of the Senate and House of Representatives as the presiding officers of those bodies shall designate."

Public Law 415, 81st Cong., 1st sess., passed 27 October 1949 (63 Stat. 936)

Unitary Wind Tunnel Plan Act of 1949

This act was Title I of P.L. 415. Title II authorized the Air Engineering Development Center.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Sec. 101. The National Advisory Committee for Aeronautics (hereinafter referred to as the "Committee") and the Secretary of Defense are hereby authorized and directed jointly to develop a unitary plan for the construction of transsonic and supersonic wind-tunnel facilities for the solution of research, development, and evaluation problems in aeronautics, including the construction of facilities at educational institutions within the continental limits of the United States for training and research in aeronautics, and to revise the uncompleted portions of the unitary plan from time to time to accord with changes in national defense requirements and scientific and technical advances. The Committee and the Secretaries of the Army, the Navy, and the Air Force are authorized to proceed with the construction and equipment of facilities in implementation of the unitary plan to the extent permitted by appropriations pursuant to existing authority and the authority contained in titles I and II of this Act. Any further implementation of the unitary plan shall be subject to such additional authorizations as may be approved by Congress.

Sec. 102. The Committee is hereby authorized, in implementation of the unitary plan, to construct and equip transsonic or supersonic wind tunnels of size, design and character adequate for the efficient conduct of experimental work in support of long-range fundamental research, at educational institutions within the Continental United States, to be selected by the Committee, or to enter into contracts with such institutions to provide for such construction and equipment, at a total cost not to exceed $10,000,000: *Provided*, That the Committee may, in its discretion, after consultation with the Committees on Armed Services of both Houses of the Congress, vest title to the facilities completed pursuant to this Section in such educational institutions under such terms and conditions as may be deemed in the best interests of the United States.

Sec. 103. (a) The Committee is hereby authorized to expand the facilities at its existing laboratories by the construction of additional supersonic wind tunnels, including buildings, equipment, and accessory construction, and by the acquisition of land and installation of utilities.

(b) There is hereby authorized to be appropriated such sums as may be necessary to carry out the purposes of this section, but not to exceed $136,000,000.

(c) The facilities authorized by this section shall be operated and staffed by the Committee but shall be available primarily to industry for testing experimental models in connection with the development of aircraft and missiles. Such tests shall be scheduled and conducted in accordance with industry's requirements and allocation of laboratory time shall be made in accordance with the public interest, with proper emphasis upon the requirements of each military service and due consideration of civilian needs.

Sec. 104. The Secretary of the Navy is hereby authorized, in implementation of the unitary plan, to expand the naval facilities at the David W. Taylor Model Basin, Carderock, Maryland, by the construction of a wind tunnel, including buildings, equipment, utilities, and accessory construction, at a cost not to exceed $6,600,000.

Sec. 105. The Committee shall submit semiannual written reports to the congress covering the selection of institutions and contracts entered into pursuant to section 102 of this title together with other pertinent information relative to the Committee's activities and accomplishments thereunder.

Public Law 472, 81st Cong., 2d sess., passed 11 April 1950 (64 Stat. 43)

An Act To promote the national defense and to contribute to more effective aeronautical research by authorizing professional personnel of the National Advisory Committee for Aeronautics to attend accredited graduate schools for research and study.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the National Advisory Committee for Aeronautics (hereinafter referred to as the NACA) is authorized to grant to any professional employee of demonstrated ability, who has served not less than one year in the NACA, a leave or leaves of absence from his regularly designated duties for the purpose of allowing such employee to carry on graduate study or research in institutions of learning accredited as such by the laws of any State.

Sec. 2. Leaves of absence may be granted under authority of this Act only for such graduate research or study as will contribute materially to the more effective functioning of the NACA.

Sec. 3. Leave or leaves of absence which may be granted to any employee under authority of this Act shall not exceed a total of one year.

Sec. 4. Tuition and other incidental academic expenses shall be borne by the employee.

Sec. 5. Any leave of absence granted under the provisions of this Act shall be without loss of salary or compensation to the employee and shall not be deducted from any leave of absence with pay authorized by any other law. Any such employee shall make a definite statement, in writing, that he will return to and, unless involuntarily separated, will remain in the service of the NACA for a period of six months if the period for which he is granted such leave of absence does not exceed twelve weeks, or for a period of one year if the period of leave exceeds twelve weeks. Any employee who does not fulfill any such commitment shall be required to reimburse the Government for the amount of leave granted under this Act.

Sec. 6. The total of the sums expended pursuant to this Act, including all sums expended for the payment of salaries or compensation to employees on leave, shall not exceed $50,000 in any fiscal year.

Public Law 672, 81st Cong., 2d sess., passed 8 August 1950 (64 Stat. 418)

An Act To promote the national defense by authorizing specifically certain functions of the National Advisory Committee for Aeronautics necessary to the effective prosecution of aeronautical research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the National Advisory Committee for Aeronautics is hereby authorized—

(a) to equip, maintain, and operate offices, laboratories, and research stations under its direction;

(b) to acquire additional land for, undertake additional construction at, and purchase and install additional equipment for, existing laboratories and research stations under its direction; and

(c) to purchase and maintain cafeteria equipment.

Sec. 2. Notwithstanding any other provision of law, the Department of Defense or any other governmental agency or any component thereof is authorized to transfer supplies, equipment, aircraft, and aircraft parts to the Committee without reimbursement: *Provided,* That such transfers shall be reported by the Committee to the Director of the Bureau of the Budget in accordance with regulations prescribed by him: *Provided further,* That this section shall not be construed as authorizing the transfer of administrative supplies or equipment: *And provided further,* That this section shall not be construed as prohibiting the loan of items of any sort to the Committee.

Sec. 3. Statutory provisions prohibiting the payment of compensation to aliens shall not apply to any persons whose employment is determined by the Committee to be necessary: *Provided,* That no such alien shall be employed until he has been cleared for such appointment as a result of an appropriate security investigation as determined by the Director of the Committee.

Sec. 4. Section 1, paragraph (b), subparagraph (3), of the Act entitled "An Act to promote the national defense by increasing the membership of the National Advisory Committee for Aeronautics, and for other purposes", approved May 25, 1948, is hereby amended by striking out the words "Flight Propulsion Laboratory" and by substituting in lieu thereof the words "Lewis Flight Propulsion Laboratory."

Sec. 5. There is hereby authorized to be appropriated, out of any money in the Treasury not otherwise appropriated, such sums of money as may be necessary for the purposes of section 1 (b) of this Act, but not to exceed $16,500,000.

Sec. 6. Appropriations made to carry out the purposes of this Act shall be available for expenses incident to construction, including Administrative overhead, planning and surveys, and shall be available until expended when specifically provided in the appropriation Act.

Sec. 7. Any projects authorized herein may be prosecuted under direct appropriations or authority to enter into contracts in lieu of such appropriation.

Public Law 759, 81st Cong., 2d sess., passed 6 September 1950 (64 Stat. 711)
Independent Offices Appropriation Act, 1951

This act stipulated "That no part of this appropriation shall be available for the operation of a field office outside the continental or territorial limits of the United States."

Public Law 384, 83d Cong., 2d sess., passed 3 June 1954 (68 Stat. 170)
An Act To promote the national defense by including a representative of the Department of Defense as a member of the National Advisory Committee for Aeronautics.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Public Law 271, Sixty-third Congress, approved March 3, 1915 (38 Stat. 930; 50 U.S.C. 151a), as amended, be amended by striking out "the chairman of the Research and Development Board of the Department of Defense" and inserting in lieu thereof "one Department of Defense representative who is acquainted with the needs of aeronautical research and development."

Public Law 584, 84th Cong., 2d sess., passed 31 July 1956 (70 Stat. 761)
Federal Executive Pay Act of 1956

Title V of this act provided for additional scientific and professional positions. Sec. 510 (b) dealt with the NACA:

> The Chairman of the National Advisory Committee for Aeronautics is authorized to establish and fix the compensation for, in the headquarters and research stations of the National Advisory Committee for Aeronautics, not to exceed thirty positions in the professional and scientific service, each such position being established in order to enable the National Advisory Committee for Aeronautics to secure and retain the services of specially qualified personnel necessary in the discharge of the duty of the Committee to supervise and direct the scientific study of the problems of flight with a view to their practical solution.

Public Law 568, 85th Cong., 2d sess., passed 29 July 1958 (72 Stat. 426)
National Aeronautics and Space Act of 1958

This act created the National Aeronautics and Space Administration. Section 301 dealt with the NACA:

> Sec. 301. (a) The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and

obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

(b) Section 2302 of title 10 of the United States Code is amended by striking out "or the Executive Secretary of the National Advisory Committee for Aeronautics." and inserting in lieu thereof "or the Administrator of the National Aeronautics and Space Administration."; and section 2303 of such title 10 is amended by striking out "The National Advisory Committee for Aeronautics." and inserting in lieu thereof "The National Aeronautics and Space Administration."

(c) The first section of the Act of August 26, 1950 (5 U.S.C. 22–1), is amended by striking out "the Director, National Advisory Committee for Aeronautics" and inserting in lieu thereof "the Administrator of the National Aeronautics and Space Administration", and by striking out "or National Advisory Committee for Aeronautics" and inserting in lieu thereof "or National Aeronautics and Space Administration".

(d) The Unitary Wind Tunnel Plan Act of 1949 (50 U.S.C. 511–515) is amended (1) by striking out "The National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee')" and inserting in lieu thereof "The Administrator of the National Aeronautics and Space Administration (hereinafter referred to as the 'Administrator')"; (2) by striking out "Committee" or "Committee's" wherever they appear and inserting in lieu thereof "Administrator" and "Administrator's", respectively; and (3) by striking out "its" wherever it appears and inserting in lieu thereof "his".

(e) This section shall take effect ninety days after the date of the enactment of this Act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this Act.

Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics

Washington, D.C.
April 23, 1915.

The President of the United States:

1. In accordance with the provisions of the Act of Congress approved March 3, 1915, authorizing the appointment of an Advisory Committee for Aeronautics, the Committee appointed by you assembled as directed by the Secretary of War at 10:00 A.M., this date, all members being present with the exception of Dr. Charles D. Walcott, Secretary of the Smithsonian Institution.

2. The Committee proceeded at once to effect a temporary organization for the purpose of formulating and submitting for your approval Rules and Regulations for the conduct of the work of the Committee.

3. After due consideration the attached "Rules and Regulations" have been adopted and are submitted for your approval.

Very respectfully,
/s/ George P. Scriven,
Brigadier General, U.S. Army, Chairman of the National Advisory Committee for Aeronautics.

RULES AND REGULATIONS
for the
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RULES

1. The Committee may exercise all the functions authorized in the Act establishing an Advisory Committee for Aeronautics.

2. The Committee, under regulations to be established and fees to be fixed, shall exercise its functions for the military and civil departments of the Government of the United States, and also for any individual, firm, association, or corporation within the United States; provided, however, that such department, individual, firm, association, or corporation shall defray the actual cost involved.

3. No funds shall be expended for the development of inventions, or for experimenting with inventions for the benefit of individuals or corporations.

REGULATIONS FOR CONDUCT OF COMMITTEE

ARTICLE I
Meetings

1. The annual meeting of the Advisory Committee shall be held in the city of Washington, in the District of Columbia, on the Thursday after the third Monday of October of each year. A semiannual meeting of the Advisory Committee shall be held on the Thursday after the third Monday in April of each year, at the same place.

2. Special meetings of the Advisory Committee may be called by the Executive Committee, by notice served personally upon or by mail or telegraph to the usual address of each member at least five days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of five members of the Advisory Committee.

4. If practicable the object of a special meeting should be sent in writing to all members, and if possible a special meeting should be avoided by obtaining the views of members by mail or otherwise, both on the question requiring the meeting and on the question of calling a special meeting.

5. Immediately after each meeting of the Advisory Committee a draft of the minutes shall be sent to each member for approval.

6. There shall be monthly meetings of the Executive Committee.

ARTICLE II
Officers

1. The officers of the Advisory Committee shall be a Chairman and a Secretary, who shall be elected by the Committee by ballot, to serve for one year.

2. The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer.

3. The Secretary shall issue notices of meetings of the Committee, record its transactions, and conduct the correspondence relating to the Committee and to the duties of his office.

ARTICLE III
Committees

1. There shall be an Executive Committee which shall consist of seven members, to be elected by the Advisory Committee by ballot from its membership, for one year. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term. The Executive Committee shall elect its Chairman.

2. The Executive Committee in accordance with the general instructions of the Advisory Committee, shall control the administration of the affairs of the Committee, and shall have general supervision of all arrangements for research, and other matters undertaken or promoted by the Advisory Committee; and shall keep a written record of all transactions and expenditures, and submit the same to the Advisory Committee at each stated meeting; and it shall also submit to the Advisory Committee, at the annual meeting, a report for transmission to the President.

3. The Executive Committee is authorized to collect aeronautical information, and such portion thereof as may be appropriate may be issued as bulletins or in other forms.

4. There may be sub-committees appointed by the Executive Committee from the membership of the Advisory Committee.

5. All officers and all members of committees hold office until their successors are elected or appointed.

ARTICLE IV
Finances

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Advisory Committee, or by authority granted by the Advisory Committee to the Executive Committee.

2. The fiscal year of the Committee shall commence on the first day of July of each year.

3. The Executive Committee shall provide for an annual audit of the accounts of the Advisory Committee, and shall submit to the annual meeting of the Advisory Committee, a full statement of the finances and work of the committees, and a detailed estimate of the proposed expenditures for the succeeding fiscal year.

4. The Paymaster General of the Navy shall be the disbursing officer for such funds as may be appropriated for the use of the Advisory Committee. The Chairman of the Advisory Committee or the Chairman of the Executive Committee, if authorized by the Advisory Committee, shall approve all accounts for the disbursement of funds.

5. Contributions of funds or collections for any purpose for aeronautics may be made to the Smithsonian Institution, and disbursements therefrom shall be made by the said institution.

ARTICLE V
Amendments

1. Amendments to these Rules and Regulations may be made at any stated meeting by a two-thirds vote of the Advisory Committee, subject to approval by the President.

April 28, 1915.

Dear Mr. President:

I sincerely regret that I was unable to attend the organization meeting of the Advisory Committee for Aeronautics, as I have taken a very deep interest in the Committee. My absence was owing to the funeral of Mrs. Walcott's father, which occurred at Bryn Mawr, on the day of the meeting.

I have given careful attention to the Rules and Regulations recommended by the Committee for your approval. I wish to call attention to one amendment that might greatly strengthen the work and influence of the Committee.

Paragraph 4, Article 3, provides for the appointment of Sub-Committees by the Executive Committee, *from the membership of the Advisory Committee.* One of the strong arguments used in securing the passage of the provision by Congress granting authority for the appointment of the Advisory Committee, was that Subcommittees could be appointed, with Chairmen selected from the membership of the Advisory Committee, and the other members from the Committee or not, as might be deemed most advisable.

My suggestion is that the rule should be amended to read as follows:

> 4. There may be Sub-Committees appointed by the Executive Committee, the Chairman of which shall be members of the Advisory Committee, and the other members may or may not be members of the Advisory Committee.

For instance, if the Chief of the Weather Bureau, who is a member of the Advisory Committee, should be requested to make an investigation of the atmosphere with relation to aeronautics, he could call to his assistance, as members of a Sub-Committee, the best qualified men in America to cooperate with him in the work, in connection with the investigations of an Advisory Committee authorized by Congress and approved by the President of the United States.

A minor suggestion is that Paragraph 4, Article 1, be omitted, as it appears to pertain to matters of administrative detail not required in the formal rules of the Committee.

I am, sir, with respect, your obedient servant,

/s/ C. D. Walcott.

June 7, 1915.

My dear General Scriven:

I must beg that you and your associates will pardon me for having taken so long in considering and coming to a conclusion about the enclosed, but I am sure that you will understand what has withdrawn my attention.

If it is still possible to make amendments of the proposed rules, I would suggest that paragraph four, article three, be amended to read,

> "There may be subcommittees appointed by the Executive Committee, the chairmen of which shall be members of the Advisory Committee, and the other members of which may or may not be members of the Advisory Committee."

I make this suggestion because it seems to me that it would be very wise indeed to leave the committee free to avail itself whenever it chose of the services of men outside of the committee who might be willing to cooperate with it. This would, of course, lie entirely within the committee's choice but might on occasion be very serviceable to it.

Cordially and sincerely yours,
/s/ WOODROW WILSON.

[This amendment was approved by the NACA Executive Committee on 11 June 1915, submitted to the president as an amendment, and approved by him on 14 June 1915.]

WASHINGTON, D.C.,
October 22, 1915.

The President:

The following amendment to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, having been adopted at the annual meeting of the committee in accordance with Article V of said Regulations, I have the honor to submit same for your approval:

Article III—COMMITTEES—Section 1

> At end of first sentence, change period to comma, and add: "and of the Secretary of the Advisory Committee, who shall be ex-officio Secretary of the Executive Committee."

The object of this change is to make the Secretary of the Advisory Committee a member also of the Executive Committee, of which he is at present merely the Secretary and not a voting member.

In addition, I have the honor to enclose a copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, as approved on June 14, 1915.

Very respectfully,
/s/ H. L. RICHARDSON,
Naval Constructor, U.S.N., Secretary.

The White House,
25 October, 1915.
Approved: /s/ WOODROW WILSON.

WASHINGTON, D.C.,
April 25, 1916.

The President:

I have the honor to submit for your approval the following amendment to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, which was adopted at the semi-annual meeting of the committee in accordance with Article V of said Regulations:

Article I—MEETINGS—Section 1

Third line, change "third" to "first", so as to read: "The annual meeting of the Advisory Committee shall be held in the City of Washington, in the District of Columbia, on the Thursday after the first Monday of October of each year.

The object of advancing the date of the annual meeting is to enable the Advisory Committee to give consideration to the preparation of estimates of expenses for the following fiscal year, which are required by law to be submitted by October 15th of each year.

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics is attached hereto. I remain,

Very respectfully,
/s/ GEORGE P. SCRIVEN,
Brigadier General, U.S.A., Chairman.

THE WHITE HOUSE
Washington

April 27, 1916.

My dear General Scriven:

Allow me to acknowledge the receipt of your letter of April twenty-fifth and to say that the amendment proposed to Section I of Article I of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, of which you advise me, has my approval.

Cordially yours,
/s/ WOODROW WILSON.

Brigadier General George P. Scriven
National Advisory Committee for Aeronautics,
State, War & Navy Building.

April 23, 1917.

The President,
The White House.
Sir:

I have the honor to transmit herewith copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics with certain amendments that have been approved by a two-thirds vote of the Advisory Committee as required by Article V of the Rules and Regulations.

The increase in the work of the Committee owing to the great development in aeronautical matters necessitates certain changes to facilitate the work of the Committee. It has been found desirable to have a secretary of the Executive Committee who may or may not be the Secretary of the Advisory Committee, which necessitates certain changes in Article III.

The Auditor has advised that a per diem allowance of $4.00 per day be made in lieu of subsistence while traveling, which is the form usually adopted by the Military Department. This is provided for in Section 5 of Article III.

The Comptroller ruled that the funds of the Committee should be expended by a special disbursing agent, and that they could not be disbursed by the Paymaster General of the Navy. The provision for this is provided for by the changes made in Article IV.

In view of the experience of the past year, the Advisory Committee recommends that amendments to the Rules and Regulations may be made by two-thirds vote of the Advisory Committee, subject to approval by the President.

I have the honor to state that the machinery of the Board is working very satisfactorily and that the matters pertaining to Aeronautics which now come before both the National Defense Council and the Naval Consulting Board are considered by the Advisory Committee for Aeronautics, and that there is the closest cooperation between the Military Departments, the National Council for Defense, and the Advisory Committee for Aeronautics.

Respectfully yours,
/s/ W. F. DURAND, *Chairman.*

Attest:
/s/ S. W. STRATTON, *Secretary.*

Approved:
/s/ WOODROW WILSON.

April 26, 1918.

The President:

I have the honor to submit for your approval the following amendments to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, which were adopted at the semiannual meeting of the committee on April 18, 1918, in accordance with Article V of said Regulations:

ARTICLE II—OFFICERS.
Section 1:
At the end of section change period to comma and add "and an Assistant Secretary who shall be appointed by the Secretary with the approval of the Executive Committee."
Add new Section 4 as follows:
"4. The Assistant Secretary shall act as administrative assistant to the Secretary, perform the usual duties of Chief Clerk, and conduct such general correspondence and perform such duties of the Secretary of the Executive Committee as may be assigned to him."

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, showing the proposed amendment, is attached hereto.

Very respectfully,
/s/ C. D. WALCOTT, *Acting Chairman.*

Attest:
/s/ S. W. STRATTON, *Secretary*

Approved:
/s/ WOODROW WILSON.

October 20, 1919.

The President:

I have the honor to submit for your approval the following amendments to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, which were adopted at the annual meeting of the committee on October 9, 1919, in accordance with Article V of said Regulations:

Article II, Section 1, line 4—After the word "an" insert "Executive Officer and an", making the section read as follows:

"1. The officers of the Advisory Committee shall be a Chairman and a Secretary, who shall be elected by the Committee by ballot, to serve for one year, and an Executive Officer and an Assistant Secretary who shall be appointed by the Secretary with the approval of the Executive Committee."

Article II, Section 4—Renumber as Section 5 and insert new Section 4 as follows:

"4. The Executive Officer shall carry into effect the orders of the Executive Committee. He shall be responsible for the general administration of its affairs, and shall make recommendations to the Executive Committee in regard to the preparation and execution of research programs, the preparation of estimates, and the allotment and expenditure of funds. He shall perform such other duties as may be assigned to him by the Executive Committee."

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, showing the proposed amendments, is attached hereto.

Very respectfully,
/s/ C. D. WALCOTT, *Chairman.*

Attest:
/s/ S. W. STRATTON, *Secretary.*

The White House,
Nov. 25, 1919.

Approved:
/s/ WOODROW WILSON.

September 23, 1922.

Mr. President:

I have the honor to submit for your approval two amendments to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, which have been duly adopted by the Committee in accordance with Article V of said Regulations:

Amendment No. 1

Article I, Section 1, first sentence—Strike out "first" and insert "third," so as to read: "The annual meeting of the Advisory Committee shall be held in the City of Washington, in the District of Columbia, on the Thursday after the third Monday of October of each year."

The purpose of this amendment is to make it more convenient for all of the members to attend the annual meeting.

Amendment No. 2

Article III, Section 1, at end of section add: "Subject to approval of the Executive Committee, he shall fix the hours of labor and rates of pay of all employees: Provided, That not less than four hours shall constitute a day's labor on Saturdays whenever Saturdays are by law, Executive Order, or custom of the community in which employed, declared or observed as half-holidays."

The purpose of this amendment is to enable the Committee to grant Saturday half-holidays the year around to its employees at Langley Field, Hampton, Virginia. The Comptroller General of the United States has advised that there would be no legal objection to the proposed regulation. Our Committee deems it desirable in the best interests of good administration. Langley Field is relatively isolated. Saturdays are not only observed as half-holidays the year around by the military establishment and its civilian employees at Langley Field, but are also generally observed as such in Hampton and Newport News, where our employees actually reside.

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, showing the proposed amendment, is attached hereto.

Very respectfully,
JOSEPH S. AMES, *Acting Chairman.*

Attest:
/s/ S. W. STRATTON, *Secretary.*

Approved: June 13/23.
/s/ WARREN G. HARDING

October 27, 1924.

Mr. President:

I have the honor to submit for your approval three amendments to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, which have been duly adopted by the Committee in accordance with Article V of said Regulations:

Amendment No. 1

Article I, Section 1—Lines 2 and 3, strike out the words "in the city of Washington in the District of Columbia"; last line, strike out the words "at the same place," so as to make this section read: "The annual meeting of the Advisory Committee shall be held on the Thursday after the third Monday of October of each year. A semiannual meeting of the Advisory Committee shall be held on the Thursday after the third Monday in April of each year."

Reason: It has been at times desirable to hold meetings of the entire Committee at the Committee's research laboratory, and it may be desirable to hold such meetings at other places.

Amendment No. 2

Article II, Section 1—Lines 4 and 5, strike out the words "an Executive Officer" and insert in lieu thereof the words "a Director of Aeronautical Research."

Reason: Years ago the need for a director of aeronautical research was recognized, but no qualified man was available. Mr. Lewis, originally employed as Executive Officer, is now qualified and has in fact been performing the duties of a director of aeronautical research. In applying the Reclassification Act, it has become desirable to appoint him as such and to discontinue the position of Executive Officer.

Amendment No. 3

Article II, Section 4, relating to duties of the Executive Officer—Strike out the entire section and substitute a new section, as follows: "The Director of Aeronautical Research shall prepare programs for the allocation and coordination of scientific research in aeronautics. He shall direct the prosecution of investigations conducted at the Langley Memorial Aeronautical Laboratory and of special investigations financed by the Committee. He shall be ex officio a member of each standing technical subcommittee. He shall conduct the correspondence relating to the duties of his office; prepare an annual report dealing with the technical activities of the Committee; and perform such other duties as may be assigned."

Reason: A revision in the statement of duties is necessitated by the change in designation from Executive Officer to Director of Aeronautical Research.

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, showing the proposed amendments, is attached hereto.

Very respectfully,
/s/ CHARLES D. WALCOTT, *Chairman.*

Attest:
/s/ D. W. TAYLOR, *Secretary.*

The White House,
October 31, 1924.
Approved: /s/ CALVIN COOLIDGE

April 27, 1927.

Mr. President:

I have the honor to submit for your approval the following amendments to the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics which were duly adopted by the Committee in accordance with Article V of said regulations at the semi-annual meeting of the entire Committee held on April 21, 1927.

Amendment No. 1

Page 1, add a new rule numbered 4 as follows:
4. The Committee may consider aeronautical inventions and designs submitted to it and make recommendations to the Patents and Design Board.

The purpose of this amendment is to provide for the discharge by the Committee of its additional duties imposed by Section 10(r) of the Army Air Corps Act, approved July 2, 1926, and amended by Act approved March 3, 1927, establishing a Patents and Design Board for the consideration of aeronautical designs favorably recommended to it by the National Advisory Committee for Aeronautics.

Amendment No. 2

Article II, Section 1, amend by inserting the words underscored* and deleting the words in parentheses.
1. The officers of the Advisory Committee shall be a Chairman and a (Secretary) **Vice Chairman,** who shall be elected by the Committee by ballot to serve for one year, and a Director of Aeronautical Research and a (an Assistant) Secretary, who shall be appointed by the (Secretary) **Chairman** with the approval of the Executive Committee.

The purpose of this amendment is to provide for a Vice Chairman to be elected from the membership of the Committee, and for the appointment by the Chairman of a Director of Aeronautical Research and a Secretary.

Amendment No. 3

Article II, Section 2, add the words underscored.
2. The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer. **In the absence of the chairman the Vice Chairman shall act as chairman.**

---

*For technical reasons, underlined copy in original has been printed in bold type.

The purpose of this amendment is to define the status of the Vice Chairman.

Amendment No. 4

Article II, Section 4, renumber as Section 3 and amend by inserting the words underscored and deleting the word in parentheses.
3. The Director of Aeronautical Research **shall execute the policies and direct the activities of the Committee.** He shall prepare programs for the allocation and coordination of scientific research in aeronautics (. He), **and** shall direct the prosecution of investigations conducted at the Langley Memorial Aeronautical Laboratory and of special investigations financed by the Committee. He shall be ex officio a member of each standing technical subcommittee. He shall conduct the correspondence relating to the duties of his office; prepare an annual report dealing with the technical activities of the Committee; and perform such other duties as may be assigned.

The purpose of this amendment is to define more clearly the duties of the Director of Aeronautical Research.

Amendment No. 5

Article II, Section 3, renumber as Section 4 and amend by adding the words underscored.
4. The Secretary shall issue notices of meetings of the Committee, record its transactions, and conduct the correspondence relating to the Committee and to the duties of his office. He shall be ex officio Secretary of the Executive Committee. **He shall direct the administrative work of the Committee and exercise general supervision over the expenditure of its funds and employment of its personnel.**

The purposes of this amendment are to provide that the Secretary of the Committee shall be the Secretary of the Executive Committee and to define more clearly the duties of the Secretary.

Amendment No. 6

Article II, Section 5, strike out entire section.

The purpose of this amendment is to abolish the present position of Assistant Secretary of the Committee.

Amendment No. 7

Article III, Section 1, Line 14, strike out "Secretary" and insert "Vice Chairman".

The purposes of this amendment are (1) to provide for the elective position of Vice Chairman of the Executive Committee, which experience has demonstrated to be advisable; and (2) to discontinue the practice of electing from the membership a Secretary of the Executive Committee, as Amendment No. 5 above provides that the Secretary of the Main Committee shall be ex officio the Secretary of the Executive Committee.

Amendment No. 8

Article III, Section 1, Line 23, before "employees" insert "administrative".

The purpose of this amendment is to define more clearly the duties of the Secretary of the Executive Committee.

Amendment No. 9

Article III, Section 5, amend by inserting the words underscored and deleting the words in parentheses.

5. Members and employees of the Advisory Committee and of subcommittees may be allowed traveling expenses and ($4.00) per diem in lieu of subsistence **as authorized by law** while traveling under orders of the Committee on official business.

The purpose of this amendment is to remove the obsolete limitation of $4.00 on the per diem in lieu of subsistence allowed in connection with official travel.

A copy of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics showing the proposed amendments is attached hereto.

Very respectfully,
/s/ JOSEPH S. AMES, *Chairman.*

Attest:
/s/ D. W. TAYLOR, *Secretary.*

The White House,
May 17, 1927.

Approved:
/s/ CALVIN COOLIDGE.

October 20, 1944.

Dear Mr. President:

Attached are two copies of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics showing amendments duly adopted by the Committee October 19, 1944, subject to your approval.

The Act of Congress, approved March 3, 1915, which established the Committee, provides that "rules and regulations for the conduct of the work of the Committee shall be formulated by the Committee and approved by the President."

The amendments proposed do not involve any substantive change in policy or procedure. They are perfecting amendments to meet changes in the law and procedure which have developed since the last revision seventeen years ago. Your approval is recommended.

Yours with respect,
/s/ J. C. HUNSAKER.

Enclosures

RULES AND REGULATIONS FOR THE CONDUCT OF THE WORK OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Approved by the President of the United States, June 14, 1915, in accordance with the provisions of an Act of Congress approved March 3, 1915 (U.S. Code, Title 49, Sec. 241).

With amendments approved by the President up to May 17, 1927.

Showing amendments adopted by the Committee October 19, 1944, subject to the President's approval: Insert matter underscored; omit matter [in parentheses].

RULES

1. The Committee may exercise all the functions authorized in the Act establishing an Advisory Committee for Aeronautics.

2. The Committee (, under regulations to be established and fees to be fixed,) shall exercise its functions for the military and civil (departments) **agencies** of the Government of the United States, and also for any individual, firm, association, or corporation within the United States; provided, however, that such (department,) individual, firm, association, or corporation shall, **under regulations to be established and fees to be fixed,** defray the actual cost involved.

3. No funds shall be expended for the development of inventions, or for experimenting with inventions for the benefit of individuals or corporations.

4. The Committee may consider aeronautical inventions and designs submitted to it and make recommendations to the Patents and Design Board.

REGULATIONS FOR CONDUCT OF COMMITTEE

ARTICLE I
Meetings

1. The annual meeting of the Advisory Committee shall be held on the fourth Thursday (after the third Monday) of October of each year. A semiannual meeting of the Advisory Committee shall be held on the fourth Thursday (after the third Monday) in April of each year.

2. Special meetings of the Advisory Committee may be called by the (Executive Committee,) Chairman, by notice served personally upon or by mail or telegraph to the usual address of each member at least five days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman, upon the (written) request of five members of the Advisory Committee.

4. If practicable the object of a special meeting should be sent in writing to all members, and if possible a special meeting should be avoided by obtaining the views of members by mail or otherwise, both on the question requiring the meeting and on the question of calling a special meeting.

5. Immediately after each meeting of the Advisory Committee a draft of the minutes shall be sent to each member for approval.

6. There shall be (monthly) meetings of the Executive Committee **approximately monthly, to be held at the call of the Chairman, Executive Committee.**

ARTICLE II
Officers

1. The officers of the Advisory Committee shall be a Chairman and a Vice Chairman, who shall be elected by the Committee by ballot to serve for one year, and a Director of Aeronautical Research, (and) a Secretary, **and an Assistant Secretary,** who shall be appointed by the Chairman with the approval of the Executive Committee.

2. The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer. In the absence of the chairman the Vice Chairman shall act as Chairman.

3. The Director of Aeronautical Research shall execute the policies and direct the activities of the Committee. He shall prepare programs for the allocation and coordination of scientific research in aeronautics, and shall direct the prosecution of investigations conducted at the (Langley Memorial Aeronautical Laboratory) **Committee's laboratories** and of special investigations financed by the Committee. He shall be ex officio a member of each standing technical subcommittee. He shall conduct the correspondence relating to the duties of his office; prepare an annual report dealing with the technical activities of the Committee and perform such other duties as may be assigned.

4. The Secretary shall issue notices of meetings of the Committee, record its transactions, and conduct the correspondence relating to the Committee and to the duties of his office, **and, upon authorization by the Chairman, may exercise functions required by law to be performed by a head of department or agency.** He shall be ex officio Secretary of the Executive Committee. He shall direct the administrative work of the Committee and exercise general supervision over the expenditure of its funds and employment of its personnel.

5. The Assistant Secretary shall supervise and direct the procurement of research equipment, the construction of research facilities, and the procurement and training of personnel, and in the absence of the Secretary shall direct work of the Committee.

ARTICLE III

1. There shall be an Executive Committee which shall consist of seven members to be elected by the Advisory Committee by ballot from its membership, for one year, and including further, any member of the Advisory Committee, not otherwise a member of the Executive Committee, but resident in or near Washington, and giving his time wholly or chiefly to the special work of the Committee. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term. The Executive Committee shall elect its Chairman and Vice Chairman. The Secretary of the Executive Committee shall issue notices of meetings of the Executive Committee, record its transactions, conduct the correspondence relating to the Committee and to the duties of his office, sign requisitions, issue travel orders, have custody of the property and records of the Committee, and supervise the work of the administrative employees. Subject to the approval of the Executive Committee, he shall fix the hours of labor and rates of pay of all employees. Provided, That not less than four hours shall constitute a day's labor on Saturdays whenever Saturdays are by law, Executive Order, or custom of the community in which employed, declared or observed as half holidays.

2. The Executive Committee, in accordance with the general instructions of the Advisory Committee, shall control the administration of the affairs of the Committee; and shall have general supervision of all arrangements for research, and other matters undertaken or promoted by the Advisory Committee; and shall keep a written records of all transactions and expenditures, and submit the same **report** to the Advisory Committee at each stated meeting; and it shall also submit to the Advisory Committee, at the annual meeting, a prepared annual report for transmission to the President.

3. The Executive Committee is authorized to collect aeronautical information, and such portion thereof as may be appropriate may be issued as bulletins or in other forms.

4. There may be **standing** subcommittees appointed by the Executive Committee, the Chairman of which shall be **officers or** members of the Advisory Committee, and the other members of which may or may not be members of the Advisory Committee. **There may also be appointed by the Executive Committee special committees and subcommittees; PROVIDED: That all appointments to standing and special committees and subcommittees shall be on an annual basis, subject to reappointment.**

5. Members and employees of the Advisory Committee and of (subcommittees) subordinate committees may be allowed traveling expenses and per diem in lieu of subsistence as authorized by law while traveling under orders of the Committee on official business.

6. All officers and all members of committees hold office until their successors are elected or appointed.

ARTICLE IV
Finances

1. No expenditures shall be authorized or made except in pursuance of (a previous allotment) **estimates approved** by the Advisory Committee or by the Executive Committee.

2. The fiscal year of the Committee shall commence on the first day of July of each year.

3. The Executive Committee shall provide for an annual audit of the accounts of the Advisory Committee, and shall submit to the annual meeting of the Advisory Committee a full statement of the finances and work of the Committee, and a detailed estimate of the proposed expenditures for the succeeding fiscal year.

4. The Executive Committee shall appoint a special disbursing agent for such funds as may be appropriated for the use of the Advisory Committee. The Chairman, or Acting Chairman, of the Executive Committee shall approve all accounts for the disbursement of funds.

5. Contributions of funds or collections for any purpose for aeronautics may be made to the Smithsonian Institution, and disbursements therefrom shall be made by the said institution.

ARTICLES V
Amendments

1. Amendments to these rules and regulations may be made by a two-thirds vote of the Advisory Committee, subject to approval by the President.

Duly adopted October 19, 1944, and recommended for the President's approval in accordance with law (U.S. Code, Title 49, Sec. 241).

/s/ J. C. HUNSAKER,
Chairman, National Advisory Committee for Aeronautics.

Approved:
/s/ FRANKLIN D. ROOSEVELT.
The White House *October 23, 1944.*

February 7, 1949.

Dear Mr. President:

In accordance with action of the National Advisory Committee for Aeronautics at its last meeting I submit herewith Amendments to Article II of its Rules and Regulations duly adopted subject to the approval of the President, as provided in the Act establishing the Committee approved March 3, 1915 (U.S.C. 1948, Title 50, Section 151).

The changes provide for:

a. A "Director" instead of a "Director of Aeronautical Research," and provide that he shall be the head of the agency in all matters except those which by law or regulation require action by the Chairman;

b. An "Executive Secretary" instead of a "Secretary." and provide that he shall be the assistant head of the agency and shall supervise and direct its administrative work;

c. An Associate Director for Research, who shall supervise and direct the scientific and technical activities of the agency; and

d. The elimination of the position of Assistant Secretary as an officer of the Committee.

The Chairman and members of the Committee meet monthly and constitute in effect a Board of Directors of a typical American business corporation, serving without compensation. They elect annually a Chairman and a Vice Chairman. The Regulations provide that "The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer. In the absence of the Chairman the Vice Chairman shall act as Chairman." The position of Chairman corresponds in effect to that of a "Chairman of the Board" of a business corporation. The Director, the Executive Secretary, and the Associate Director for Research, are the full time career executives whose relations to the main Committee, to each other, and to the staff of approximately 7,000 employees, are quite similar to those of a President, Executive Vice President, and General Manager of a corporation. They are the executive officers of the organization who actually manage its affairs.

The purpose of the changes proposed is to clarify and define the status, duties, and relationship of the new positions of Director, Executive Secretary, and Associate Director for Research.

Respectfully,
/s/ J. C. HUNSAKER, *Chairman.*

AMENDMENTS TO REGULATIONS

Submitted for Approval of the President

February 7, 1949

ARTICLE II
Officers

1. The officers of the Advisory Committee shall be a Chairman and a Vice Chairman, who shall be elected by the Committee by ballot to serve for one year, and a Director (of Aeronautical Research), **an Executive** Secretary, and an (Assistant Secretary) **Associate Director for Research,** who shall be appointed by the Chairman with the approval of the Executive Committee. **The Executive Secretary shall serve as Secretary of the Committee.**

2. The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer. In the absence of the Chairman the Vice Chairman shall act as Chairman.

3. The Director (of Aeronautical Research) shall execute the policies and direct the activities of the Committee, **and shall be the head of the agency in matters except those which by law or regulation require action by the Chairman.** He shall prepare programs for the allocation and coordination of scientific research in aeronautics, and shall direct the prosecution of investigations conducted at the Committee's laboratories and of special investigations financed by the Committee. He shall be ex officio a member of each standing technical subcommittee. He shall conduct the correspondence relating to the duties of his office; prepare an annual report dealing with the technical activities of the Committee and perform such other duties as may be assigned.

4. The **Executive** Secretary shall **be the assistant head of the agency and shall supervise and direct its administrative work. He shall** issue notices of meetings of the Committee, record its transactions, and conduct the correspondence relating to the Committee and to the duties of his office, and, upon authorization by the (Chairman,) Director, may exercise functions required by law to be performed by a head of department or agency. He shall be ex officio Secretary of the Executive Committee. (He shall direct the administrative work of the Committee and exercise general supervision over the expenditure of its funds and employment of its personnel.)

5. The (Assistant Secretary) **Associate Director for Research** shall supervise and direct the (procurement of research equipment, the construction of research facilities, and the procurement and training of personnel, and in the absence of the Secretary shall direct the administrative work of the Committee) **scientific and technical activities of the agency.**

Approved: /s/ HARRY S TRUMAN.

MAY 3, 1949.

Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics

Approved by the President of the United States, June 14, 1915, in accordance with the provisions of an Act of Congress approved March 3, 1915 (U.S. Code, Title 50, Sec. 151).
With amendments approved by the President up to May 3, 1949.

RULES

1. The Committee may exercise all the functions authorized in the Act establishing an Advisory Committee for Aeronautics.

2. The Committee shall exercise its functions for the military and civil agencies of the Government of the United States, and also for any individual, firm, association, or corporation within the United States; provided, however, that such individual, firm, association, or corporation shall, under regulations to be established and fees to be fixed, defray the actual cost involved.

3. No funds shall be expended for the development of inventions, or for experimenting with inventions for the benefit of individuals or corporations.

4. The Committee may consider aeronautical inventions and designs submitted to it and make recommendations to the Patents and Design Board.

REGULATIONS FOR CONDUCT OF COMMITTEE

ARTICLE I
Meetings

1. The annual meeting of the Advisory Committee shall be held on the fourth Thursday of October of each year. A semiannual meeting of the Advisory Committee shall be held on the fourth Thursday in April of each year.

2. Special meetings of the Advisory Committee may be called by the Chairman, by notice served personally upon or by mail or telegraph to the usual address of each member at least five days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman, upon the request of five members of the Advisory Committee.

4. If practicable the object of a special meeting should be sent in writing to all members, and if possible a special meeting should be avoided by obtaining the views of

members by mail or otherwise, both on the question requiring the meeting and on the question of calling a special meeting.

5. Immediately after each meeting of the Advisory Committee a draft of the minutes shall be sent to each member for approval.

6. There shall be meetings of the Executive Committee approximately monthly, to be held at the call of the Chairman, Executive Committee.

ARTICLE II
Officers

1. The Officers of the Advisory Committee shall be a Chairman and a Vice Chairman, who shall be elected by the Committee by ballot to serve for one year, and a Director, an Executive Secretary, and an Associate Director for Research, who shall be appointed by the Chairman with the approval of the Executive Committee. The Executive Secretary shall serve as Secretary of the Committee.

2. The Chairman shall preside at all meetings of the Committee and shall have the usual powers of a presiding officer. In the absence of the Chairman the Vice Chairman shall act as Chairman.

3. The Director shall execute the policies and direct the activities of the Committee, and shall be the head of the agency in all matters except those which by law or regulation require action by the Chairman. He shall prepare programs for the allocation and coordination of scientific research in aeronautics, and shall direct the prosecution of investigation conducted at the Committee's laboratories and of special investigations financed by the Committee. He shall be ex officio a member of each standing technical subcommittee. He shall conduct the correspondence relating to the duties of his office; prepare an annual report dealing with the technical activities of the Committee and perform such other duties as may be assigned.

4. The Executive Secretary shall be the assistant head of the agency and shall supervise and direct its administrative work. He shall issue notices of meetings of the Committee, record its transactions, and conduct the correspondence relating to the Committee and to the duties of his office, and, upon authorization by the Director, may exercise functions required by law to be performed by a head of department or agency. He shall be ex officio Secretary of the Executive Committee.

5. The Associate Director for Research shall supervise and direct the scientific and technical activities of the Agency.

ARTICLE III
Committees

1. There shall be an Executive Committee which shall consist of seven members to be elected by the Advisory Committee by ballot from its membership, for one year, and including further, any member of the Advisory Committee, not otherwise a member of the Executive Committee, but resident in or near Washington, and giving his time wholly or chiefly to the special work of the Committee. Any member elected to fill a

vacancy shall serve for the remainder of his predecessor's term. The Executive Committee shall elect its Chairman and a Vice Chairman. The Secretary of the Executive Committee shall issue notices of meetings of the Executive Committee, record its transactions, conduct the correspondence relating to the Committee and to the duties of his office.

2. The Executive Committee in accordance with the general instructions of the Advisory Committee, shall control the administration of the affairs of the Committee; shall have general supervision of all arrangements for research, and other matters undertaken or promoted by the Advisory Committee; shall keep a written record of all transactions and expenditures, and report to the Advisory Committee at each stated meeting; and shall also prepare an annual report for transmission to the President.

3. The Executive Committee is authorized to collect aeronautical information, and such portion thereof as may be appropriate may be issued as bulletins or in other forms.

4. There may be standing committees appointed by the Executive Committee, the Chairmen of which shall be officers or members of the Advisory Committee, and the other members of which may or may not be members of the Advisory Committee. There may also be appointed by the Executive Committee special committees and subcommittees; PROVIDED: That all appointments to standing and special committees and subcommittees shall be on an annual basis, subject to reappointment.

5. Members and employees of the Advisory Committee and of subordinate committees may be allowed traveling expenses and per diem in lieu of subsistence as authorized by law while traveling under orders of the Committee on official business.

6. All officers and all members of committees hold office until their successors are elected or appointed.

ARTICLE IV
Finances

1. No expenditures shall be authorized or made except in pursuance of estimates approved by the Advisory Committee or by the Executive Committee.

2. The fiscal year of the Committee shall commence on the first day of July of each year.

3. The Executive Committee shall submit to the annual meeting of the Advisory Committee a full statement of the finances and work of the Committee, and a detailed estimate of the proposed expenditures for the succeeding fiscal year.

ARTICLE V
Amendments

1. Amendments to these rules and regulations may be made by a two-thirds vote of the Advisory Committee, subject to approval by the President.

Appendix B
Committees

Introduction

Public Law 271 (63d Cong., 1st sess.), passed 3 March 1915, established the National Advisory Committee for Aeronautics, to consist of twelve members: two each from the army and navy, one each from the Smithsonian Institution, the Weather Bureau, and the National Bureau of Standards, and five from private life, the last to "be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences." The ratio of seven government members to five private members reflected an intent that the Committee serve the interests of the government, not any faction or sector of the private community.

Public Law 908 (70th Cong., 1st sess.), approved 2 March 1929, increased the membership from twelve to fifteen. It did not state whether the additional members were to be from government or private life, only that they were to meet the qualifications established for private members in the organic act. One purpose of this legislation was to provide openings on the Committee for representatives of the aeronautical branch of the Department of Commerce, created by the Air Commerce Act of 1926. Between 1929 and 1933, one representative of Commerce sat on the Committee, making a ratio of eight government members to seven private. Thereafter, two representatives of Commerce always sat on the Committee, making the ratio for a time nine to six. In 1938, this custom was made mandatory by the Civil Aeronautics Act (P.L. 706; 75th Cong., 2d sess.), approved 23 June.

In 1948, the ratio of government to private members was changed again by Public Law 549 (80th Cong., 2d sess.), approved 25 May. This law raised the number of members to seventeen. The army representatives became air force representatives, and the government total was increased to ten by the addition of a representative of the new Department of Defense. Again, as in 1929, the law did not say whether the remaining seven members were to be drawn from private life or government service.

Most Committee appointments from government service were ex officio: i.e., the incumbent of a post like head of the air force or secretary of the Smithsonian Institution was automatically appointed to the NACA. Length of service on the Committee depended on tenure in the government post, and this varied from agency to agency. Until 1938, appointments from private life were until the incumbent resigned; after 1938, they were for five years, though often renewed. These policies resulted in a wide variation in average length of service as a Committee member:

Army	3.03* years
Navy	2.84**
Smithsonian	11
Weather Bureau	14.67
Bureau of Standards	8.8
Private	8.72
Commerce	2.63
Defense Department	1.57

*One member served twice; these figures count him only once.

**Two members served twice; one served three times; these figures count each of them only once.

The high rotation rate in the military services obviously put them at a disadvantage compared to the other members. This was partially countered by allowing each service two chairs. Seldom were both incumbents from the same service rotated together, so there was more continuity in their representation than these figures suggest. The Department of Commerce also had two seats to compensate for its high rate of turnover; the Department of Defense did not.

Table B–1 is a complete listing of all members; Table B–2 is a summary of the history of each NACA chair. A total of 120 men served on the NACA, some of them more than once, some in more than one chair. Two men who served on the Committee in 1958 never received formal appointment because of the pending reconstitution of the NACA.

The Executive Committee was the real governing body of the NACA. Whereas the Main Committee met only semiannually, the Executive Committee met almost monthly. Until 1933, its members were chosen annually by vote of the Main Committee. The usual practice was to elect all members of the Main Committee who resided in the Washington area and who could devote a reasonable amount of time to Committee work. After 1933, all members of the Main Committee automatically belonged to the Executive Committee, but that did not greatly alter the situation. The Washington members—usually the government members—still dominated the Executive Committee.

The NACA always had a problem of terminology with its committees, one that still exists. Since the NACA was itself a committee, all the technical committees it spawned were actually subcommittees, and were for a while so called. But some of these had subcommittees of their own, inviting the label of sub-subcommittee. Moreover, members of the NACA were accustomed to creating ad hoc committees at the drop of a controversy. The titling of these could become still more complex.

To avoid confusion, the following arbitrary system has been adopted in this volume. The hierarchy of committees is described as:

- *The Committee.* (NACA) The National Advisory Committee for Aeronautics; the Main Committee. In keeping with the NACA policy, the definite article is always used with these terms, even though the usage seems awkward today. Though contemporaries in Europe spoke of NACA (spoken Nacka), its name in the United States was always "the NACA" (i.e., the N-A-C-A).

- *Committee.* (C) This term refers to main technical subcommittees of the NACA. Their unique attribute was that they all were in existence after World War I and none of them were subcommittees of other technical committees. There were eleven, of which four—Power Plants for Aircraft, Aerodynamics, Aircraft Construction, and Operating Problems—had subcommittees.

During World War I, 32 subcommittees of the NACA were formed. All but seven of them were officially "committees." Only two of them, however, are termed committees in this volume, the two that survived the 1919 reorganization. All the rest were terminated at the end of the war; in their brief existence they more closely resembled what the NACA would later call subcommittees. In fact, even during the war, they were often referred to as subcommittees of the NACA.

- *Subcommittee.* (SC) This was a body subordinate to another committee, usually one of the main technical committees. Most often it was formed to give advice on a specialized branch of the larger field of aeronautics for which its parent committee was responsible: e.g., the Lubrication and Wear Subcommittee of the Committee on Power Plants for Aircraft. Sometimes subcommittees were formed to deal with specific problems and disbanded when the problem was solved: e.g., the Subcommittee on the Research Program on Monocoque Design—which was also an example of a subcommittee of a subcommittee (Aircraft Structures).

- *Special Committee.* (SpC) This irregular body was formed ad hoc to deal with occasional problems, usually political or institutional; for instance, the Special Committee on the Site for New Engine Research Facility or the Special Committee on Personnel.

- *Special Subcommittee.* (SpSC) This body was also formed ad hoc to deal with occasional problems. These problems, however, were most often technical, as in the case of the Special Subcommittee on the Upper Atmosphere and the Special Subcommittee on Research Problems of Transonic Aircraft Design. Special subcommittees were often converted into standing subcommittees, as for example Rocket Engines and Vibration and Flutter.

Within these general categories are many anomalies. Some subcommittees, like Meteorological Problems, had different parent committees at different times. Aircraft Construction, at different points in its existence, was both a committee and a subcommittee. Jet Propulsion was a special committee, a committee, and a subcommittee. Many of these bodies changed names and functions over the years while retaining a core identity that lent continuity to their existence.

The following tables reconstruct, as simply as possible, the most important technical committees in NACA's history. The criterion for inclusion is their mention in the NACA Annual Reports. Many other ad hoc committees existed over the years, as the NACA conducted virtually all its business by committee, especially in the early years. The 108 technical committees on the list (under 145 different titles) were the most important. Through them one can trace the Committee's interests and activities over the years—and the changing state of aeronautical science as well.

Table B-3 lists alphabetically all the technical committees that appeared in the annual reports. Some committees changed their names as time went on. For these, one name appears as the committee's permanent title, usually the one the committee ended with or the one that most clearly identifies its major interest. Other titles held by the committee at various times appear only as cross references to the main entry. Thus, entries for Subcommittees on Supercharger Compressors and Compressors refer the reader to the Subcommittee on Compressors and Turbines, the name held by the committee during its last and longest incarnation. Unless otherwise noted, the full title of all of these technical committees is Committee on . . . or Subcommittee on . . ., etc.

Table B-4 lists all the main technical committees, their other titles, their chairmen, and the subcommittees and special subcommittees subordinate to them. Table B-5 lists all the standing subcommittees, their parent committees, other titles, and chairmen. The remarks section notes those that were clearly successors to other subcommittees. Table B-6 lists all the special committees and their chairmen; none of these had other titles or subcommittees. Table B-7 lists all the special subcommittees, including some that were later converted to standing subcommittees. This table also lists the parent committees and the chairmen; none of these had other titles.

Tables B-4 through B-7 list the committees in chronological order by year of origin, and alphabetically within each year group.

Table B-8 lists the numbers of each type of technical committee by year, as given in the annual report for each year. It shows a fairly steady pattern of growth up to World War II. The war brought on a spate of special committees and subcommittees;

in the last years of the war, the NACA settled into the pattern that was to dominate its remaining existence.

Table B-9 shows the composition of the technical committees at 10-year intervals from 1918 to 1958. Members are classified by affiliation. The category *Government, Military* applies to representatives of the armed forces, whether uniformed officers or not. *Government, Civilian* includes all others in the service of the federal government. *Private, Industry* includes all those whose principal activity was employment in the aviation industry (either manufacture or operations) or a directly related industry like fuels or instrumentation.

Table B-1
Members of the NACA Main Committee, 1915-1958

Parentheses around name indicate no formal appointment. Boldface under date of service indicates membership on initial or final Committee. Parentheses around affiliation indicate nongovernment.

	Years of Service	Representing
Abbot, Charles G.: Vice chairman, EC, 1938-1943	6/29/28-1/25/45	Smithsonian
Adams, Joseph F.	11/21/52-12/31/56	CAB
Alison, John R.	8/25/47-4/1/49	Commerce
Ames, Joseph S.: Chairman, EC, 1920-1937; Chairman, NACA, 1927-1939	**4/2/15**-10/7/39	(Johns Hopkins)
Arnold, Henry H.	10/10/38-4/12/46	Army
Astin, Allen V.	6/5/52-9/30/58	NBS
Bane, Thurman H.	5/2/19-12/15/22	Army
Bassett, Preston R.	12/3/53-**9/30/58**	(Sperry Rand Corp.)
Brett, George H.	3/11/39-1/23/42	Army
Briggs, Lyman J.: Vice chairman, NACA, 1942-1945	7/14/33-11/19/45	NBS
Bristol, Mark L.	**4/2/15**-1/10/17	Navy
Bronk, Detlev W.: Vice chairman, NACA, 1953-1955; Vice chairman, EC, 1955-1958	6/25/48-9/30/58	(U. of Penn.), NRC
Burden, William A. M.	8/8/42-7/1/47	Commerce
Burgess, George K.	5/26/23-7/2/32	NBS
Bush, Vannevar: Vice chairman, NACA, 1939; Chairman, NACA, 1940-8/1/41; Chairman, EC, 1938-8/1/41	8/23/38-11/1/48 6/25/48-11/1/48	(Carnegie Institution) RDB
Carmichael, Leonard: Vice chairman, NACA, 1956-1958	1/14/53-**9/30/58**	Smithsonian
Cassady, John H.	3/11/50-5/13/52	Navy
Clark, V. E.	2/5/17-6/6/18	Army
Combs, Thomas S.	9/16/52-8/2/56	Navy
Compton, Karl T.	11/1/48-11/10/49	RDB
Condon, Edward U.	11/19/45-9/30/51	NBS
Connolly, Donald H.	9/5/40-3/19/42	CAA
Cook, Arthur B.	5/23/31-6/1/39	Navy
Craigie, Laurence C.	12/15/51-4/19/54	Air Force
Craven, Thomas T.	9/29/19-3/10/21	Navy
Crawford, Frederick C.	12/16/54-**9/30/58**	(Thompson Products, Inc.)
Curry, John F.	7/10/24-12/21/26	Army

	Years of Service	Representing
Damon, Ralph S.	12/3/53-1/4/56	(Trans World Airlines, Inc.)
Davis, Thomas W. S.	2/27/50-1/20/53	Commerce
Doolittle, James H.: Chairman, NACA, 1957-1958; Chairman, EC, 1957-1958	6/25/48-9/30/58	(Shell Oil Co.)
Duncan, Donald B.	2/24/47-1/27/48	Navy
Durand, William F.: Chairman, NACA, 1917-1918	**4/2/15**-11/29/33 7/23/41-8/24/45	(Stanford U.) (Stanford U)
Echols, O. P.	1/23/42-6/11/45	Army
Fagg, Fred D.	4/23/37-4/16/38	(Northwestern U.)
Fechet, James E.	1/6/28-12/19/31	Army
Fitch, Aubrey W.	8/17/44-7/24/45	Navy
Foote, Paul D.	10/22/57-**9/30/58**	DoD
Foulois, Benjamin D.	8/5/29-9/10/30 1/5/32-1/25/36	Army Army
Freeman, John R.: Chairman, NACA, 10/10/18-8/1/19	6/1/18-8/1/19	(Consultant)
Furnas, Clifford C.	1/6/56-2/15/57	DoD
Gardner, Matthias B.	5/13/52-3/15/53	Navy
Gillmore, William E.	12/21/26-8/5/29	Army
Gregg, Willis R.: Chairman, EC, 1937-1938	10/10/34-9/14/38	Weather Bureau
Guggenheim, Harry F.	4/5/29-8/23/38	(Guggenheim Foundation)
Harrison, Lloyd.	7/8/53-7/31/55	Navy
Hayford, John F.	**4/2/15**-5/26/23	(Northwestern U.)
Hazen, Ronald M.	4/8/46-12/1/54	(General Motors)
Hester, Clinton M.	8/23/38-8/2/40	CAA
Hinckley, Robert H.	5/20/39-7/1/42	CAA
Hines, Wellington T.	7/18/57-**9/30/58**	Navy
Hunsaker, Jerome C: Chairman, NACA, 8/1/41-1956; Chairman, EC, 8/1/41-1956	10/14/22-12/8/23 8/23/38-**9/30/58**	Navy (MIT)
Kenly, William L.	6/6/18-3/10/19	Army
Kilner, Walter G.	12/1/39-3/12/40	(Retired)
King, Ernest J.	7/19/33-6/15/36	Navy
Kraus, Sydney M.	6/17/36-3/19/43	Navy
Land, Emory S.	12/8/23-6/25/29	Navy
Lindbergh, Charles A.	11/6/31-12/1/39	(None)
Littlewood, William.	2/10/44-12/1/53	(American Airlines)
Lonnquest, Theodore C.	6/19/47-9/16/52	Navy
McCain, John S.	10/6/42-7/31/44	Navy
McCarthy, Charles J.	1/14/57-9/30/58	(Chance Vought Aircraft, Inc.)
MacCracken, William P., Jr., Vice chairman, EC, 10/21/37-8/22/38	4/5/29-8/22/38	Commerce
McIntosh, Lawrence W.	1/5/23-6/30/24	Army
Marvin, Charles F.	**4/2/15**-8/31/34	Weather Bureau
Mead, George J.: Vice chairman, NACA, 1940-1942	10/11/39-12/1/43	(United Aircraft Corp.)

	Years of Service	Representing
Menoher, Charles T.	5/2/19-10/21/21	Army
Mitscher, Marc A.	7/24/45-1/14/46	Navy
Moffett, William A.	3/10/21-4/4/33	Navy
Mulligan, Denis.	4/16/38-8/23/38	Commerce
Murray, Robert B.	7/10/53-1/26/54	Commerce
Newton, Byron R.	**4/2/15**-6/1/18	Treasury
Noble, Edward J.	8/23/38-4/26/39	CAA
Nyrop, Donald W.	4/24/51-10/31/52	CAB
Ofstie, Ralph A.	3/30/53-3/5/55	Navy
Pace, Ernest M.	4/9/43-10/4/44	Navy
Patrick, Mason M.	10/21/21-12/13/27	Army
Pfingstag, Carl J	8/1/55-5/17/57	Navy
(Pirie, Robert B. [acting])	5/22/58-**9/30/58**	Navy
Powers, Edwards M.	6/11/45-3/22/49	Army, Air Force
Pratt, Henry C.	9/10/30-3/23/35	Army
Price, John Dale.	1/27/48-3/11/50	Navy
Pupin, Michael I.	**4/2/15**-10/16/22	(Columbia U.)
Putt, Donald L.	3/22/49-6/30/58	Air Force
Pyle, James T.	3/1/57-**9/30/58**	CAA
Quarles, Donald A.	3/2/54-1/6/56	DoD
Radford, Arthur W.	1/17/46-2/1/56	Navy
Raymond, Arthur E.	4/8/46-12/1/56	(Douglas Aircraft Co.)
Reber, Samuel	**4/2/15**-5/26/16	Army
Reichelderfer, Francis W.	1/2/39-**9/30/58**	Weather Bureau
Rentzel, Delos W.	5/18/48-4/9/51	CAA
Richardson, Holden C.: Secretary, NACA, 1916; Secretary, EC, 1916	**4/2/15**-2/10/17	Navy
Richardson, Lawrence B.	10/11/44-12/1/46	Navy
Rickenbacker, Edward V.	4/14/56-**9/30/58**	(Eastern Air Lines, Inc.)
Robins, Augustine W.	3/23/35-3/11/39	Army
Rothschild, Louis S.	5/13/55-**9/30/58**	Commerce
Ryan, Oswald.	1/27/54-12/31/54	CAB
Sabine, Wallace C.	6/6/18-11/30/18	Army
Saville, Gordon P.	10/19/50-7/31/51	Air Force
Scriven, George P.	**4/2/15**-2/15/17	Army
Spaatz, Carl.	4/12/46-6/2/48	Army, Air Force
Squier, George O.	5/29/16-6/6/18	Army
Stevens, Leslie C.	12/1/46-6/16/47	Navy
Stratton, Samuel W.: Secretary, NACA, 1917-1923; Secretary, EC, 1917-1923	**4/2/15**-5/26/23 5/26/23-10/18/31	NBS (MIT)
Taylor, David W.: Secretary, NACA, 1924-1927; Secretary, EC, 1924-1927; Vice chairman, NACA, 1927-1938; Vice chairman, EC, 1927-1937	2/16/17-10/14/22 10/16/22-8/23/38	Navy (Retired)
Towers, John H.	1/10/17-8/16/19 7/6/29-5/23/31 5/20/39-9/28/42	Navy Navy Navy
Twining, Nathan F.	4/19/43-8/26/57	Air Force
Vandenberg, Hoyt S.	6/2/48-10/19/50	Air Force

	Years of Service	Representing
Vidal, Eugene L.	11/29/33–4/23/37	Commerce
Walcott, Charles D.: Chairman, EC, 1915–1919; Chairman, NACA, 1920–1927	4/2/15–2/9/27	Smithsonian
Warner, Edward P.	4/5/29–5/14/42	(*Aviation* magazine)
	5/14/42–9/20/45	CAB
Webster, William.	3/10/50–7/19/51	DoD
Westover, Oscar.	1/25/36–9/21/38	Army
Wetmore, Alexander: Vice chairman, NACA, 1948–1952	1/20/45–12/31/52	Smithsonian
Weyerbacher, Ralph D.	5/31/34–6/15/36	Navy
White, Thomas D.	8/26/57–**9/30/58**	Air Force
Whitman, Walter G.	8/9/51–7/31/53	DoD
(Wilson, Roscoe C. [acting])	6/30/58–**9/30/58**	Air Force
Wright, Orville	1/29/20–1/30/48	(Retired)
Wright, Theodore P.: Vice chairman, NACA, 1946–1947	5/14/42–4/8/46	(Cornell U.)
	4/8/46–5/18/48	CAA
	5/18/48–12/1/53	(Cornell U.)

Table B–2

History of Each Chair on the Main Committee

POSITION 1. Filled by the army until 1947, thereafter by the air force. During World War I, the chief of the Aviation Section of the Signal Corps or the Chief Signal Officer filled the chair. Thereafter, except for 1950–1954, the most senior air officer held the post. Between World Wars I and II, the rank of the incumbent was major general; thereafter, with two exceptions, it was general.

1915–1916	Samuel Reber
1916–1918	George O. Squier
1918–1919	William L. Kenly
1919–1921	Charles T. Menoher
1921–1927	Mason M. Patrick
1928–1931	James E. Fechet
1932–1936	Benjamin D. Foulois
1936–1938	Oscar Westover
1938–1946	Henry H. Arnold
1946–1948	Carl Spaatz
1948–1950	Hoyt S. Vandenberg
1950–1951	Gordon P. Saville
1951–1954	Laurence C. Craigie
1954–1957	Nathan F. Twining
1957–1958	Thomas D. White

POSITION 2. Filled by the army until 1947, thereafter by the air force. The incumbent was generally the head of the engineering, materiel, or research and development services for the air forces. The rank of the incumbent rose slowly at first, from captain in 1917 to major in 1926. After that, the incumbent was always a flag officer, by 1958 a lieutenant general.

1915–1917	George P. Scriven
1917–1918	Virginius E. Clark
1918–1919	Wallace C. Sabine
1919–1922	Thurman H. Bane
1923–1924	Lawrence W. McIntosh
1924–1926	John F. Curry
1926–1929	William E. Gillmore
1929–1930	Benjamin D. Foulois
1930–1935	Henry C. Pratt
1935–1939	Augustine W. Robins
1939–1942	George H. Brett
1942–1945	Oliver P. Echols
1945–1949	Edwards M. Powers
1949–1958	Donald L. Putt
1958	Roscoe C. Wilson (acting)

POSITION 3. After World War I, this chair was filled by the chief naval aviation officer, the head of the Bureau of Aeronautics (a rear admiral) until 1944, thereafter the Deputy Chief of Naval Operations (air), a vice admiral.

1915–1917	Holden C. Richardson
1917–1919	John H. Towers
1919–1921	Thomas T. Craven
1921–1933	William A. Moffett
1933–1936	Ernest J. King
1936–1939	Arthur B. Cook
1939–1942	John S. Towers
1942–1944	John S. McCain
1944–1945	Aubrey W. Fitch
1945–1946	Marc A. Mitscher
1946–1947	Arthur W. Radford
1947–1948	Donald B. Duncan
1948–1950	John D. Price
1950–1952	John H. Cassady
1952–1953	Matthias B. Gardner
1953–1955	Ralph A. Ofstie
1955–1956	Thomas S. Combs
1956–1958	William V. Davis, Jr.
1958	Robert B. Pirie (acting)

POSITION 4. After World War I, this chair was held by a representative of the technical branch of naval aviation, generally the asistant chief or other ranking officer of the Bureau of Aeronautics. After Rear Adm. Taylor resigned in 1922, the rank of the incumbent varied between captain and commander until World War II. A rear admiral held the chair from 1943 on.

1915–1916	Mark L. Bristol
1917–1922	David W. Taylor
1922–1923	Jerome C. Hunsaker
1923–1929	Emory S. Land
1929–1931	John H. Towers
1931–1934	Arthur B. Cook
1934–1936	Ralph D. Weyerbacher
1936–1943	Sidney M. Kraus
1943–1944	Ernest M. Pace, Jr.
1944–1946	Lawrence B. Richardson
1946–1947	Leslie C. Stevens
1947–1952	Theodore C. Lonnquest
1952–1953	Thomas S. Combs
1953–1955	Lloyd Harrison
1955–1957	Carl J. Pfingstag
1957–1958	Willington T. Hines

POSITION 5. Always held by the Secretary of the Smithsonian Institution.

1915–1927	Charles D. Walcott
1928–1945	Charles G. Abbot
1945–1952	Alexander Wetmore
1952–1958	Leonard Carmichael

POSITION 6. Always held by the Chief of the Weather Bureau.

1915–1934	Charles F. Marvin
1934–1938	Willis R. Gregg
1938–1958	Francis W. Reichelderfer

POSITION 7. Always held by the Director of the National Bureau of Standards.

1915–1923	Samuel W. Stratton
1923–1932	George K. Burgess
1933–1945	Lyman J. Briggs
1945–1951	Edward U. Condon
1952–1958	Allen V. Astin

POSITION 8. Held from 1915 to 1939 by Joseph S. Ames, professor of physics and later president of Johns Hopkins University, and chairman of the NACA,1927–1939. Thereafter, the chair was held by industry representatives; the first, George J. Mead, was also the first man from the aviation industry to sit on the main committee. His three successors each came from aircraft operating firms.

1915–1939	Joseph S. Ames
1939–1943	George J. Mead
1944–1953	William Littlewood
1953–1956	Ralph S. Damon
1956–1958	Edward V. Rickenbacker

POSITION 9. Until 1948, this chair was held by three longstanding Committee members from private life; thereafter it was held by the Department of Defense representative: the chairman of the Research and Development Board until 1953, thereafter by the Assistant Secretary of Defense (Research and Engineering).

1915–1922	Michael I. Pupin
1922–1938	David W. Taylor
1938–1948	Vannevar Bush
1948–1949	Karl T. Compton
1950–1951	William Webster
1951–1953	Walter G. Whitman
1954–1956	Donald A. Quarles
1956–1957	Clifford C. Furnas
1957–1958	Paul D. Foote

POSITION 10. After William F. Durand, an original member, resigned this chair in 1933, it was held by representatives of various aeronautical activities in the Department of Commerce. Until 1938, this was a courtesy; thereafter, it was required by law.

1915–1933	William F. Durand
1933–1937	Eugene L. Vidal
1937–1938	Fred D. Fagg, Jr.
1938	Denis Mulligan
1938–1939	Edward J. Nobel
1939–1942	Robert H. Hinckley
1942–1947	William A. M. Burden
1947–1949	John R. Alison
1950–1953	Thomas W. S. Davis
1953–1954	Robert B. Murray, Jr.
1954	Oswald Ryan
1955–1958	Louis S. Rothschild

POSITION 11. The incumbent of this chair was always a private citizen. Until World War II, academics or retirees held the chair; thereafter, representatives of aircraft engine manufacturers.

1915–1923	John F. Hayford
1923–1931	Samuel W. Stratton
1931–1939	Charles A. Lindbergh
1939–1940	Walter G. Kilner
1940–1941	Robert E. Doherty
1941–1945	William F. Durand
1946–1954	Ronald M. Hazen
1954–1958	Frederick C. Crawford

POSITION 12. After World War I, during which a representative of the Coast Guard held this chair, it was occupied by representatives from various walks of private life.

1915–1918	Byron R. Newton
1918–1919	John R. Freeman
1920–1948	Orville Wright
1948–1953	Theodore P. Wright
1953–1958	Preston R. Bassett

After 1929

POSITION 13. Held by a representative of the Commerce Department until 1938, thereafter by Jerome C. Hunsaker of MIT, chairman of the NACA from 1941 to 1956.

1929–1938	William P. MacCracken, Jr.
1938–1958	Jerome C. Hunsaker

POSITION 14. Held by a private member until 1938, thereafter by the Administrator of Civil Aeronautics or a member of the Civil Aeronautics Board.

1929–1938	Harry F. Guggenheim
1938–1940	Clinton M. Hester
1940–1942	Donald H. Connolly
1942–1945	Edward P. Warner
1946–1948	Theodore P. Wright
1948–1951	Delos W. Rentzel
1951–1952	Donald W. Nyrop
1952–1956	Joseph P. Adams
1957–1958	James T. Pyle

POSITION 15. Held by private members; after World War II, by representatives of the airframe manufacturing industry.

1929–1942	Edward P. Warner
1942–1946	Theodore P. Wright
1946–1956	Arthur E. Raymond
1957–1958	Charles J. McCarthy

After 1948

POSITION 16. Held by James H. Doolittle, doctor of science (MIT), vice president of Shell Oil Company, and chairman of the NACA, 1956–1958.

1948–1958	James H. Doolittle

POSITION 17. Held by Detlev W. Bronk, physicist and physiologist at the University of Pennsylvania, president of Johns Hopkins University (1948–1953), president of Rockefeller University (1953–1968), and president of the National Academy of Sciences (1950–1962).

1948–1958	Detlev W. Bronk

Table B-3
Alphabetical List of Committee Titles

Aerial Mail Service (SC), 1917
Aero Torpedoes (SC), 1917
Aerodynamic Problems of Transport Construction and Operation (SpSC), 1936
Aerodynamic Stability and Control (SC), 1946–1958
Aerodynamics (CC), 1919–1958
Aeronautic Instruments (SC), 1916–1917
Aeronautical Inventions and Designs (C), 1927–1941
Aeronautical Nomenclature (SC), 1916 (see Nomenclature for Aeronautics)
Aeronautical Research Facilities (SpC), 1939
Aeronautical Research in Educational Institutions (SpC), 1935
Aeronautical Research in Universities (SC), 1928–1930
Aircraft Accidents (C), 1928–1941
Aircraft Communications (SC), 1917
Aircraft Construction (C), 1919–1958
Aircraft Design and Associated Engineering Problems (SC), 1918
Aircraft Fire Prevention (SC), 1948–1954
Aircraft Fuels (SC), 1935–1958
Aircraft Fuels and Lubricants (SC), 1935–1947 (see Aircraft Fuels)
Aircraft Loads (SC), 1948–1958
Aircraft Materials (C), 1936–1943 (see Aircraft Construction)
Aircraft Metals (SC), 1920–1947
Aircraft Methods (see Aircraft Metals) (SC), 1946
Aircraft, Missile, and Spacecraft Aerodynamics (C), 1958 (see Aerodynamics)
Aircraft, Missile, and Spacecraft Construction (C), 1958 (see Aircraft Construction)
Aircraft, Missile, and Spacecraft Propulsion (C), 1958 (see Power Plants for Aircraft)
Aircraft Noise (SpSC,SC), 1952–1958
Aircraft Operating Problems (C), 1958 (see Operating Problems)
Aircraft Structural Design (SC), 1944–1947 (See Aircraft Structures)
Aircraft Structural Materials (SC), 1948–1958
Aircraft Structures (SC,C), 1927–1934, 1935–1943, 1948–1957
Aircraft Structures and Materials (C), 1935 (see Aircraft Construction)
Airplane Mapping Committee (SC), 1917
Airships (SC), 1927–1940
Automatic Stabilization and Control (SC), 1956–1958
Bibliography of Aeronautics (SC), 1916–1918
Buildings, Laboratories, and Equipment (SC), 1917–1918
Civil Aerial Transport (SC), 1917–1918
Combustion (SC), 1945–1958
Compressors (SC), 1945–1950 (see Compressors and Turbines)
Compressors and Turbines (SpSC, SC), 1940–1958
Coverings, Dopes, and Protective Coatings (SC), 1920–1930
Deicing Problems (SpSc, SC) 1941–1947 (see Aerodynamics, Icing Problems)
Design, Construction, and Navigation of Aircraft (SC), 1916–1917
Design of Army Semirigid Airship RS-1 (SpC), 1923–1925
Design of Navy Rigid Airship ZR-1 (SpC), 1923
Editorial (SC), 1917–1918
Encouragement and Regulation of Aircraft in Commerce (SpC), 1926

Engine Performance and Operation (SC), 1951-1958
Engine Research Facilities (SpC), 1939-1940
Engineering Problems (SpC), 1917
Exhaust Gas Turbines (SC), 1942 (see Turbines)
Exhaust Gas Turbines and Intercoolers (SpSC), 1940-1941 (see Turbines)
Fireproof Coverings (SC), 1918
Flight Safety (SC), 1955-1958
Fluid Mechanics (SC), 1949-1958
Foreign Representatives (SC), 1917-1919
Free Flight Tests (SC), 1917-1918
Fuel Injection Engine (SC), 1918
Fuels (SC), 1958 (see Aircraft Fuels)
Future Research Facilities (SpC), 1938-1939
Governmental Relations (C), 1916-1930
Heat Exchangers (SC), 1942-1946
Heat-Resisting Alloys (SpSC, SC), 1944-1946 (see Heat-Resisting Materials)
Heat-Resisting Materials (SC), 1944-1958
Helicopter, or Direct-Lift Aircraft (SC), 1917
Helicopters (SC), 1943-1958
High-Speed Aerodynamics (SC), 1946-1958
Icing Problems (SpSC, SC), 1941-1957
Induction-System De-Icing (SpSC, SC), 1940-1946
Industry Consulting (C), 1945-1958
Instruments (SC), 1928-1935
Internal Aerodynamics (SC), 1946-1958 (see Internal Flow)
Internal Flow (SC), 1947-1958
Jet and Turbine Power Plants (SC), 1944 (see Jet Propulsion)
Jet Propulsion (SpC, C, SC), 1941-1944
Landing Fields and Flying Routes (SC), 1918
Light Alloys (SC), 1917-1918
Lightning Hazards to Aircraft (SpSC, SC), 1938-1945
Loads (SC), 1958 (see Aircraft Loads)
Low Speed Aerodynamics (SC), 1957-1958 (see Propellers for Aircraft)
Lubrication and Wear (SC), 1942-1958
Lubrication, Friction, and Wear (SC), 1942-1947 (see Lubrication and Wear)
Materials for Aircraft (C), 1919-1934 (see Aircraft Construction)
Materials Research Coordination (SpC), 1944-1946
Metals (SC), 1920-1934 (see Aircraft Metals)
Metals for Turbosupercharger Wheels and Buckets (SpSC, SC), 1941, 1943
Metals Used in Aircraft (SC), 1935-1943 (see Aircraft Metals)
Meteorological Problems (SC), 1928-1958
Methods and Devices for Testing Aircraft Material and Structures (SC), 1931-1935
Miscellaneous Materials (SC), 1931-1934 (see Miscellaneous Materials and Accessories)
Miscellaneous Materials and Accessories (SC), 1931-1943
Motive Power (C), 1916 (see Power Plants for Aircraft)
Navigation of Aircraft, Aeronautic Instruments, and Accessories (SC), 1918
Nomenclature for Aeronautics (SC), 1916-1918
Nonmetallic Aircraft Materials (SC), 1947 (see Wood and Plastics for Aircraft)
Operating Problems (C), 1942-1958
Patents (SC), 1917
Patents and Design Board (SpC), 1926

Personnel (SpC), 1918
Personnel, Buildings, and Equipment (C), 1919-1941
Policy (SC), 1917
Power Plant Controls (SC), 1952-1958
Power Plant Materials (SC), 1956-1958 (see Heat-Resisting Materials)
Power Plants (C), 1917 (see Power Plants for Aircraft)
Power Plants for Aircraft (C), 1916-1958
Problems of Air Navigation (C), 1928-1935
Problems of Communication (SC), 1928-1930
Procedures for Unitary Facilities (SpC), 1954
Propellers for Aircraft (SC), 1940-1958
Propulsion Systems (SC), 1945-1948 (see Propulsion-Systems Analysis)
Propulsion-Systems Analysis (SC), 1945-1950
Publications and Intelligence (C), 1919-1938
Quarters (SC), 1917
Radiator Design (SC), 1916-1917
Recovery of Power from Exhaust Gas (SC), 1943-1944 (see Turbines)
Relation of the Atmosphere to Aeronautics (SC), 1916-1918
Relation of the National Advisory Committee for Aeronautics to National Defense in Time of War (SpC), 1938
Research Problems of Transonic Aircraft Design (SpSC), 1948
Research Program on Monocoque Design (SC), 1931-1936
Rocket Engines (SpSC, SC), 1951-1958
Rotating-Wing Aircraft (SC), 1940-1942
Seaplanes (SC), 1935-1958
Self-Propelled Guided Missiles (SpC), 1945-1947
Site for Experimental Field (SC), 1916
Site for New Engine-Research Facility (SpC), 1940
Site Inspection [for New Engine-Research Facility] (SpC), 1940
Space Technology (SpC), 1958
Specifications for Aeronautic Instruments (SC), 1916 (see Aeronautic Instruments)
Stability and Control (SC), 1946-1955 (see Aerodynamic Stability and Control)
Standardization and Investigation of Materials (SC), 1916-1918
Standardization and Investigation of Materials for Aircraft (SC), 1918 (see Standardization and Investigation of Materials)
Steel Construction for Aircraft (SC), 1917-1918
Structural Loads and Methods of Structural Analysis (SC), 1935 (see Aircraft Structures)
Structural Materials (SC), 1958 (see Aircraft Structural Materials)
Structures (SC), 1958 (see Aircraft Structures)
Supercharger Compressors (SpSc, SC), 1940-1944 (see Compressors and Turbines)
Surplus Aircraft Research (SpC), 1946
To Direct Research in Applied Structures (SpSC), 1938-1941
To Make Survey of Techniques and Equipment for Elastic Examination of Large Aircraft Structures in Lieu of Destruction Tests (SpSC), 1938-1941
Turbines (SC), 1940-1950
Upper Atmosphere (SpSC), 1946-1951
Vibration and Flutter (SpSC, SC), 1936, 1938-1958
Vibration of Dual-Rotation Propellers for Aircraft (SC), 1942
Welding Problems (SpSC, SC) 1941, 1943
Wood and Plastics for Aircraft (SC), 1944-1947
Woods and Glues (SC), 1920-1930

Table B-4
Chronological List of NACA Committees

GOVERNMENTAL RELATIONS, 1916-1930
Chairmen
Charles D. Walcott, 1916-1926
Charles F. Marvin, 1927-1930

POWER PLANTS FOR AIRCRAFT, 1916-1958
Other Titles
Motive Power, 1916
Power Plants, 1917
Power Plants for Aircraft, 1918-1957
Aircraft, Missile, and Spacecraft Propulsion, 1958
Chairmen
Samuel W. Stratton, 1916-1931
George W. Lewis, 1931-1932 (acting)
William P. MacCracken, 1932-1937
Vannevar Bush, 1938
George J. Mead, 1939-1943
William Littlewood, 1944-1945
Ronald M. Hazen, 1946-1954
Frederick C. Crawford, 1955-1958
Subcommittees
Fuel Injection Engine, 1918
Aircraft Fuels, 1935-1958
Compressors and Turbines, 1940-1958
Induction-System De-Icing, 1940-1946
Turbines, 1940-1950
Jet Propulsion, 1944
Heat Exchangers, 1942-1946
Lubrication and Wear, 1942-1948
Heat-Resisting Materials, 1944-1958
Combustion, 1945-1958
Propulsion-Systems Analysis, 1945-1950
Engine Performance and Operation, 1951-1958
Rocket Engines, 1951-1958
Power Plant Controls, 1952-1958

AERODYNAMICS, 1919-1958
Other Titles
Aerodynamics, 1919-1957
Aircraft, Missile, and Spacecraft Aerodynamics, 1958
Chairmen
John F. Hayford, 1919-1922
Joseph F. Ames, 1923-1926
David W. Taylor, 1927-1934
Edward P. Warner, 1935-1941
Theodore P. Wright, 1942-1953
Preston R. Bassett, 1953-1958

Subcommittees
Airships, 1927–1940
Aeronautical Research in Universities, 1928–1930
Meteorological Problems, 1928–1958
Seaplanes, 1935–1958
Propellers for Aircraft, 1940–1958
Rotating-Wing Aircraft, 1940–1942
Vibration of Dual-Rotation Propellers for Aircraft, 1942
Helicopters, 1943–1958
Aerodynamic Stability and Control, 1946–1958
High-Speed Aerodynamics, 1946–1958
Internal Aerodynamics, 1946–1958
Fluid Mechanics, 1949–1958
Automatic Stabilization and Control, 1956–1958
Special Subcommittees
Aerodynamic Problems of Transport Construction and Operation, 1936
Vibration and Flutter, 1936, 1938–1939
Lightning Hazards to Aircraft, 1938–1941, 1943–1944
Deicing Problems, 1941
Upper Atmosphere, 1946–1951
Research Problems of Transonic Aircraft Design, 1948
Remarks
Successor to the Subcommittee on Aircraft Design and Associated Engineering Problems (1918).

AIRCRAFT CONSTRUCTION, 1919–1958
Other Titles
Materials for Aircraft, 1919–1934
Aircraft Structures and Materials, 1935
Aircraft Materials, 1936–1943
Aircraft Construction, 1944–1957
Aircraft, Missile, and Spacecraft Construction, 1958
Chairmen
Samuel W. Stratton, 1919
Charles F. Marvin, 1920–1922
George K. Burgess, 1923–1932
H. L. Whittemore, 1932–1933 (acting)
Lyman J. Briggs, 1933–1945
Arthur E. Raymond, 1946–1956
Charles J. McCarthy, 1957–1958
Subcommittees
Aircraft Metals, 1920–1947
Coverings, Dopes, and Protective Coatings, 1920–1930
Woods and Glues, 1920–1930
Aircraft Structures, 1927–1934, 1944–1958
Methods and Devices for Testing Aircraft Material and Structures, 1931–1935
Miscellaneous Materials and Accessories, 1931–1943
Research Program on Monocoque Design, 1931–1936
Metals for Turbosupercharger Wheels and Buckets, 1941–1943
Welding Problems, 1942
Wood and Plastics for Aircraft, 1944–1947

Aircraft Loads, 1948-1958
Aircraft Structural Materials, 1948-1958
Vibration and Flutter, 1948-1958
Special Subcommittees
To Direct Research in Applied Structures, 1938-1941
To Make Survey of Techniques and Equipment for Elastic Examination of Large Aircraft Structures in Lieu of Destruction Tests, 1938-1941
Welding Problems, 1941, 1943
Remarks
Successor to the Subcommittee on Buildings, Laboratories, and Equipment (1917-Aircraft), 1916-1918. Divided into two committees from 1936 through 1943.

PERSONNEL, BUILDINGS, AND EQUIPMENT, 1919-1941
Chairmen
Joseph S. Ames, 1919-1938
Vannevar Bush, 1939-1940
Jerome C. Hunsaker, 1941
Remarks
Successor to the Subcommittee on Buildings, Laboratories, and Equipment (1917-1918) and the Special Committee on Personnel (1918). Note that the chairman of the NACA served as chairman of this committee.

PUBLICATIONS AND INTELLIGENCE, 1919-1938
Chairman
Joseph S. Ames, 1919-1938
Remarks
Successor to the Subcommittee on Bibliography of Aeronautics (1916-1918), and Editorial Subcommittee (1916-1918), and the Subcommittee on Foreign Representatives (1917-1919).

AERONAUTICAL INVENTIONS AND DESIGNS, 1927-1941
Chairmen
David W. Taylor, 1927-1934
Lyman J. Briggs, 1935-1941

AIRCRAFT ACCIDENTS, 1928-1941
Chairmen
George K. Burgess, 1928-1930
Edward P. Warner, 1931-1942
Remarks
Derived from a special committee on nomenclature, subdivision, and classification of aircraft accidents, 1928.

PROBLEMS OF AIR NAVIGATION, 1928-1935
Chairman
William P. MacCracken, 1928-1935

OPERATING PROBLEMS, 1942-1958
Other Titles
Operating Problems, 1942-1957
Aircraft Operating Problems, 1958

Chairmen
Edward P. Warner, 1942–1945
William Littlewood, 1946–1953
Ralph S. Damon, 1954–1955
Edward V. Rickenbacker, 1956–1958
Subcommittees
Aircraft Fire Prevention, 1948–1954
Aircraft Noise, 1952–1958
Flight Safety, 1955–1958
Icing Problems, 1942–1957
Lightning Hazards to Aircraft, 1942, 1945
Meteorological Problems, 1942–1958

INDUSTRY CONSULTING, 1945–1958
Chairmen
Lawrence D. Bell, 1945
J. H. Kindelberger, 1946
Lawrence D. Bell, 1947
H. Mansfield Horner, 1948
John K. Northrup, 1949
Robert E. Gross, 1950
Dwayne L. Wallace, 1951
William M. Allen, 1952
Ralph S. Damon, 1953
Mundy I. Peale, 1954
C. W. LaPierre, 1955
William Littlewood, 1956
Leonard S. Hobbs, 1957
John L. Atwood, 1958

Table B–5
Chronological List of NACA Subcommittees

AERONAUTIC INSTRUMENTS, 1916–1917
Subcommittee of
Design, Construction, and Navigation of Aircraft
Other Titles
Specifications for Aeronautic Instruments, 1916
Chairman
Joseph S. Ames, 1916–1917
Remarks
Succeeded by Subcommittee on Navigation of Aircraft, Aeronautic Instruments and Accessories in 1918.

BIBLIOGRAPHY OF AERONAUTICS, 1916–1918
Subcommittee of
NACA
Chairman
Charles F. Marvin, 1916–1918

DESIGN, CONSTRUCTION, AND NAVIGATION OF AIRCRAFT, 1916–1917
Subcommittee of
NACA
Chairman
George O. Squier, 1916–1917
Remarks
Succeeded in 1918 by the Subcommittee on Aircraft Design and Associated Engineering Problems and the Subcommittee on Navigation of Aircraft, Aeronautic Instruments and Accessories.

NOMENCLATURE FOR AERONAUTICS, 1916–1918
Subcommittee of
NACA
Other Titles
Aeronautical Nomenclature, 1916
Chairman
Joseph S. Ames, 1916–1918

RADIATOR DESIGN, 1916–1917
Subcommittee of
NACA
Chairman
Holden C. Richardson, 1916–1917

RELATION OF THE ATMOSPHERE TO AERONAUTICS, 1916–1918
Subcommittee of
NACA
Chairman
Charles F. Marvin, 1916–1918

SITE FOR EXPERIMENTAL FIELD, 1916

Subcommittee of

NACA

Chairman

Charles D. Walcott, 1916

STANDARDIZATION AND INVESTIGATION OF MATERIALS, 1916–1918

Subcommittee of

NACA

Other Titles

Standardization and Investigation of Materials, 1916–1917

Standardization and Investigation of Materials for Aircraft, 1918

Chairman

Samuel W. Stratton, 1916–1918

Remarks

Succeeded in 1919 by the Committee on Materials for Aircraft.

AERIAL MAIL SERVICE, 1917

Subcommittee of

NACA

Chairman

George O. Squier, 1917

AERO TORPEDOES, 1917

Subcommittee of

NACA

Chairman

John H. Towers, 1917

AIRCRAFT COMMUNICATIONS, 1917

Subcommittee of

NACA

Chairman

Michael I. Pupin, 1917

AIRPLANE MAPPING COMMITTEE, 1917

Subcommittee of

NACA

Chairman

George O. Squier, 1917

BUILDINGS, LABORATORIES, AND EQUIPMENT, 1917–1918

Subcommittee of

NACA

Chairman

Samuel W. Stratton, 1917–1918

Remarks

Succeeded in 1919 by the Committee on Personnel, Buildings, and Equipment.

CIVIL AERIAL TRANSPORT, 1917-1918
Subcommittee of
NACA
Chairman
William F. Durand, 1917-1918

EDITORIAL, 1917-1918
Subcommittee of
NACA
Chairman
Joseph S. Ames, 1917-1918
Remarks
Succeeded in 1919 by the Committee on Publications and Intelligence.

FOREIGN REPRESENTATIVES, 1917
Subcommittee of
NACA
Chairman
Charles D. Walcott, 1917
Remarks
Succeeded in 1919 by the Committee on Publications and Intelligence.

FREE FLIGHT TESTS, 1917-1918
Subcommittee of
NACA
Chairman
John F. Hayford, 1917-1918

HELICOPTER, OR DIRECT-LIFT AIRCRAFT, 1917
Subcommittee of
NACA
Chairman
William F. Durand, 1917
Remarks
Disbanded 1917; replaced 1940-1942 by the Subcommittee on Rotating-Wing Aircraft.

LIGHT ALLOYS, 1917-1918
Subcommittee of
Standardization and Investigation of Materials
Chairman
George K. Burgess, 1917-1918

PATENTS, 1917
Subcommittee of
NACA
Chairman
Charles D. Walcott, 1917

POLICY, 1917
Subcommittee of
NACA
Chairman
John F. Hayford, 1917

QUARTERS, 1917
Subcommittee of
NACA
Chairman
Samuel W. Stratton, 1917

STEEL CONSTRUCTION FOR AIRCRAFT, 1917–1918
Subcommittee of
NACA, 1917
Aircraft Design and Associated Engineering Problems, 1918
Chairman
William F. Durand, 1917–1918

AIRCRAFT DESIGN AND ASSOCIATED ENGINEERING PROBLEMS, 1918
Subcommittee of
NACA
Chairman
William F. Durand, 1918
Remarks
Succeeded the Committee on Design, Construction, and Navigation of Aircraft (1916–1917) and the Special Committee on Engineering Problems, 1917.

FIREPROOF COVERINGS, 1918
Subcommittee of
Aircraft Design and Associated Engineering Problems
Chairman
Joseph S. Ames, 1918

FUEL INJECTION ENGINE, 1918
Subcommittee of
Power Plants for Aircraft
Chairman
Leigh M. Griffith, 1918

LANDING FIELDS AND FLYING ROUTES, 1918
Subcommittee of
Civil Aerial Transport
Chairman
H. M. Byllesby, 1918
Remarks
Colonel Byllesby was the only nonmember of the NACA to chair a subcommittee during World War I.

NAVIGATION OF AIRCRAFT, AERONAUTIC INSTRUMENTS AND ACCESSORIES, 1918
Subcommittee of
NACA
Chairman
Joseph S. Ames, 1918
Remarks
Succeeded the Subcommittee on Aeronautic Instruments (1916–1917) and the Subcommittee on Design, Construction, and Navigation of Aircraft (1916–1917).

AIRCRAFT METALS, 1920–1947
Subcommittee of
Aircraft Construction
Other Titles
Metals, 1920–1934
Metals Used in Aircraft, 1935–1943
Aircraft Metals, 1944–1945, 1947
Aircraft Methods, 1946
Chairmen
George K. Burgess, 1920–1924
H. W. Gillette, 1925–1928
H. S. Rawdon, 1929–1943
A. W. Winston, 1944–1945
Paul F. Voigt, 1946–1947
Remarks
Abolished in 1948 when the Subcommittee on Aircraft Structural Materials was created.

COVERINGS, DOPES, AND PROTECTIVE COATINGS, 1920–1930
Subcommittee of
Aircraft Construction
Chairman
Henry A. Gardner, 1920–1928
Charles H. Helms, 1929–1930
Remarks
Consolidated into the Subcommittee on Miscellaneous Materials in 1931.

WOODS AND GLUES, 1920–1930
Subcommittee of
Aircraft Construction
Chairmen
H. L. Whittemore, 1920–1924
George W. Trayer, 1925–1930
Remarks
Consolidated into the Subcommittee on Miscellaneous Materials in 1931.

AIRCRAFT STRUCTURES, 1927–1958
Subcommittee of
Materials for Aircraft, 1927–1934
Aircraft Construction, 1944–1958

Other Titles
Aircraft Structures, 1927–1934
Structural Loads and Methods of Structural Analysis, 1935
Committee on Aircraft Structures, 1935–1943
Aircraft Structural Design, 1944–1947
Aircraft Structures, 1948–1957
Structures, 1958
Chairmen
Starr Truscott, 1927–1936
Lyman J. Briggs, 1937–1943
Richard L. Templin, 1944–1948, 1953
Charles R. Strang, 1949–1952
George R. Ray, 1954–1956
C. H. Stevenson, 1957–1958
Remarks
Technically discharged in 1936, but actually elevated to committee status by division of the former Committee on Aircraft Structures and Materials. Rejoined with Aircraft Materials in 1944, and reconstituted as a subcommittee.

AIRSHIPS, 1927–1940
Subcommittee of
Aerodynamics
Chairmen
Edward P. Warner, 1927–1937
Jerome C. Hunsaker, 1938–1940

AERONAUTICAL RESEARCH IN UNIVERSITIES, 1928–1930
Subcommittee of
Aerodynamics
Chairman
Charles F. Marvin, 1928–1930
Remarks
Abolished as its work was taken over by other groups.

INSTRUMENTS, 1928–1935
Subcommittee of
Problems of Air Navigation
Chairman
Lyman J. Briggs, 1928–1935
Remarks
Functions overlapped those of the Bureau of Air Commerce. Absorbed in the Subcommittee on Miscellaneous Materials and Accessories.

METEOROLOGICAL PROBLEMS, 1928–1958
Subcommittee of
Problems of Air Navigation, 1928–1934
Aerodynamics, 1935–1941
Operating Problems, 1942–1958
Chairmen
Charles F. Marvin, 1929–1933
Willis Ray Gregg, 1934–1937
Francis W. Reichelderfer, 1938–1958

PROBLEMS OF COMMUNICATION, 1928–1930

Subcommittee of

Problems of Air Navigation

Chairman

Lloyd Espenschiel, 1928–1930

Remarks

Discontinued because its functions duplicated those of a committee of the aeronautics branch of the Department of Commerce.

METHODS AND DEVICES FOR TESTING AIRCRAFT MATERIALS AND STRUCTURES, 1931–1935

Subcommittee of

Aircraft Construction

Chairman

Henry J. E. Reid, 1931–1935

Remarks

Completed its assignment in 1935 with the publication of special reports; work in this field thereafter handled by the Subcommittee on Structural Loads and Methods of Structural Analysis.

MISCELLANEOUS MATERIALS AND ACCESSORIES, 1931–1943

Subcommittee of

Aircraft Construction

Other Titles

Miscellaneous Materials, 1931–1934

Miscellaneous Materials and Accessories, 1935–1943

Chairmen

Charles H. Helms, 1931–1934

Warren E. Emley, 1935–1943

Remarks

Successor to the Subcommittee on Coverings, Dopes, and Protective Coatings (1920–1930) and the Subcommittee on Woods and Glues (1920–1930). Abolished in 1944, when the Aircraft Construction Committee was formed.

RESEARCH PROGRAM ON MONOCOQUE DESIGN, 1931–1936

Subcommittee of

Aircraft Structures of the Committee on Aircraft Construction

Chairman

George W. Lewis, 1931–1936

Remarks

Discharged when the Committee on Aircraft Structures and Materials was divided.

AIRCRAFT FUELS, 1935–1958

Subcommittee of

Power Plants for Aircraft

Other Titles

Aircraft Fuels and Lubricants, 1935–1947

Aircraft Fuels, 1948–1957

Fuels, 1958

Chairmen
H. C. Dickinson, 1935–1938
George W. Lewis, 1939
Walter G. Whitman, 1940–1945
William H. Holaday, 1946–1949
J. Bennett Hill, 1950–1952
Daniel P. Barnard, 1953–1955
John L. Cooley, 1956–1957
James A. Reid, 1958

SEAPLANES, 1935–1958
Subcommittee of
Aerodynamics
Chairmen
Holden C. Richardson, 1935–1937, 1941–1945
Jerome C. Hunsaker, 1938–1940
Grover Loening, 1946–1952
Ernest G. Stout, 1953–1955
Robert S. Hatcher, 1956–1958

VIBRATION AND FLUTTER, 1936, 1938–1958
Subcommittee of
Aerodynamics, 1936, 1938–1947
Aircraft Construction, 1948–1958
Chairmen
Henry J. E. Reid, 1936, 1938–1948
Raymond L. Bisplinghoff, 1949–1951
Martin Goland, 1952–1958

LIGHTNING HAZARDS TO AIRCRAFT, 1938–1945
Subcommittee of
Aerodynamics, 1938–1941
Operating Problems, 1942–1945
Chairman
Delbert M. Little, 1938–1945

COMPRESSORS AND TURBINES, 1940–1958
Subcommittee of
Power Plants for Aircraft
Other Titles
Supercharger Compressors, 1940–1944
Compressors, 1945–1950
Compressors and Turbines, 1951–1958
Chairmen
Val Cronstedt, 1940–1941
Kenneth Campbell, 1942–1945
John H. Marchant, 1946
Opie Chenoweth, 1947
Arnold H. Redding, 1948
Howard W. Emmons, 1949–1951
Walter Doll, 1952–1955
John M. Wetzler, 1956–1957
George F. Wislicenus, 1958

Remarks
Absorbed the existing Subcommittee on Turbines in 1951.

INDUCTION-SYSTEM DE-ICING, 1940–1946
Subcommittee of
Power Plants for Aircraft
Chairmen
William C. Lawrence, 1940–1945
Arthur A. Brown, 1946

PROPELLERS FOR AIRCRAFT, 1940–1958
Subcommittee of
Aerodynamics
Other Titles
Propellers for Aircraft, 1940–1956
Low Speed Aerodynamics, 1957–1958
Chairmen
Frank W. Caldwell, 1940–1946
Fred E. Weick, 1947
George S. Schairer, 1948–1949
Thomas B. Rhines, 1950–1952
George W. Brady, 1953–1955
Daniel H. Jacobson, 1956
R. Richard Heppe, 1957–1958

ROTATING-WING AIRCRAFT, 1940–1942
Subcommittee of
Aerodynamics
Chairman
John Easton, 1940–1942

TURBINES, 1940–1950
Subcommittee of
Power Plants for Aircraft
Other Titles
Exhaust Gas Turbines and Intercoolers, 1940–1941
Exhaust Gas Turbines, 1942
Recovery of Power from Exhaust Gas, 1943–1944
Turbines, 1944–1950
Chairmen
Opie Chenoweth, 1940–1941
John G. Lee, 1942–1947
Ronald B. Smith, 1948
Arnold H. Redding, 1949–1950
Remarks
Merged in 1951 with the Subcommittee on Compressors and Turbines.

ICING PROBLEMS, 1941–1957
Subcommittee of
Aerodynamics, 1941
Operating Problems, 1942–1957

Other Titles
Deicing Problems, 1941–1947
Icing Problems, 1948–1957
Chairmen
D. W. Tomlinson, 1941
Karl Larson, 1942–1945
Lewis A. Rodert, 1946–1947
Wilson H. Hunter, 1948
R. L. Brien, 1949–1950
Arthur A. Brown, 1951–1952
Wilbur W. Reaser, 1953–1957

JET PROPULSION, 1941–1944
Subcommittee of
Power Plants for Aircraft, 1944
Other Titles
Jet Propulsion, 1941–1943
Jet and Turbine Power Plants, 1944
Chairman
William F. Durand, 1941–1944
Remarks
A Special Committee in 1941 and 1943; a Committee in 1942. Abolished when the Subcommittee on Propulsion Systems was created in 1945.

METALS FOR TURBOSUPERCHARGER WHEELS AND BUCKETS, 1941, 1943
Subcommittee of
Aircraft Construction
Chairman
William L. Badger, 1941–1943
Remarks
Succeeded in 1944 by the Special Subcommittee on Heat-Resisting Alloys.

WELDING PROBLEMS, 1941–1943
Subcommittee of
Aircraft Construction
Chairmen
G. F. Jenks, 1941–1942
E. S. Jenkins, 1943
Remarks
Abolished in 1944, when the Aircraft Construction Committee was formed.

HEAT EXCHANGERS, 1942–1946
Subcommittee of
Power Plants for Aircraft
Chairman
W. H. McAdams, 1942–1946
Remarks
Created when the Special Subcommittee on Exhaust Gas Turbines and Intercoolers was changed to the Exhaust Gas Turbines Subcommittee.

LUBRICATION AND WEAR, 1942–1958

Subcommittee of

Power Plants for Aircraft

Other Titles

Lubrication, Friction, and Wear, 1942–1947

Lubrication and Wear, 1948–1958

Chairmen

R. J. S. Pigott, 1942–1944

Arthur Underwood, 1945–1949

E. M. Phillips, 1950–1952

Robert G. Larsen, 1953–1956

Frank W. Wellons, 1957–1958

Remarks

Changed to Lubrication and Wear when Aircraft Fuels and Lubricants was changed to Aircraft Fuels.

VIBRATION OF DUAL-ROTATION PROPELLERS FOR AIRCRAFT, 1942

Subcommittee of

Aerodynamics

Chairman

Frank W. Caldwell, 1942

HELICOPTERS, 1943–1958

Subcommittee of

Aerodynamics

Chairmen

Grover Loening, 1943–1948

Richard H. Prewitt, 1949–1951

Bartram Kelley, 1952–1955

Lee L. Douglas, 1956–1958

Remarks

Successor to Subcommittee on Rotating-Wing Aircraft (1940–1942), which had been preceded by the Subcommittee on Helicopters, or Direct-Lift Aircraft (1917).

HEAT-RESISTING MATERIALS, 1944–1958

Subcommittee of

Power Plants for Aircraft

Other Titles

Heat-Resisting Alloys, 1944–1946

Heat-Resisting Materials, 1947–1955

Power Plant Materials, 1956–1958

Chairmen

William L. Badger, 1944–1946, 1953–1955

Norman L. Mochel, 1947–1949

Arthur W. F. Green, 1950–1952

Rudolph H. Thielemann, 1956–1958

Remarks

Formed after the discharge of the Special Subcommittee on Metals for Turbosupercharger Wheels and Buckets.

WOOD AND PLASTICS FOR AIRCRAFT, 1944–1947
Subcommittee of
Aircraft Construction
Other Titles
Wood and Plastics for Aircraft, 1944–1946
Nonmetallic Aircraft Materials, 1947
Chairman
Gordon M. Kline, 1944–1947
Remarks
Succeeded in 1948 by the Subcommittee on Aircraft Structural Materials.

COMBUSTION, 1945–1958
Subcommittee of
Power Plants for Aircraft
Chairmen
Addison M. Rothrock, 1945
Glenn C. Williams, 1946–1948
Bernard Lewis, 1949–1951
John P. Longwell, 1952–1954
Alfred G. Cattaneo, 1955–1958

PROPULSION-SYSTEMS ANALYSIS, 1945–1950
Subcommittee of
Power Plants for Aircraft
Other Titles
Propulsion Systems, 1945–1948
Propulsion-Systems Analysis, 1949–1950
Chairman
Joseph H. Keenan, 1945–1950
Remarks
Incorporated the former Subcommittee on Jet Propulsion; abolished in 1951 after creation of the Special Subcommittee on Rocket Engines.

AERODYNAMIC STABILITY AND CONTROL, 1946–1958
Subcommittee of
Aerodynamics
Other Titles
Stability and Control, 1946–1955
Aerodynamic Stability and Control, 1956–1958
Chairmen
L. E. Root, 1946
Walter S. Diehl, 1947–1958

HIGH-SPEED AERODYNAMICS, 1946–1958
Subcommittee of
Aerodynamics
Chairmen
Hugh L. Dryden, 1946–1947
Russell G. Robinson, 1948
L. E. Root, 1949
John G. Lee, 1950–1951
Allen E. Puckett, 1952–1955
Clark B. Millikan, 1956–1958

INTERNAL FLOW, 1946–1958

Subcommittee of

Aerodynamics

Other Titles

Internal Aerodynamics, 1946

Internal Flow, 1947–1958

Chairmen

Joseph H. Keenan, 1947

Stewart Way, 1948–1950

Philip A. Colman, 1951–1953

William J. O'Donnell, 1954–1958

AIRCRAFT FIRE PREVENTION, 1948–1954

Subcommittee of

Operating Problems

Chairmen

Lewis A. Rodert, 1948–1949

Raymond D. Kelley, 1950–1954

Remarks

Succeeded by the Subcommittee on Flight Safety.

AIRCRAFT LOADS, 1948–1958

Subcommittee of

Aircraft Construction

Other Titles

Aircraft Loads, 1948–1957

Loads, 1958

Chairmen

Richard L. Schleicher, 1948

George Snyder, 1949–1951

Jerome F. McBrearty, 1952–1956

Ralph B. Davidson, 1957–1958

AIRCRAFT STRUCTURAL MATERIALS, 1948–1958

Subcommittee of

Aircraft Construction

Other Titles

Aircraft Structural Materials, 1948–1957

Structural Materials, 1958

Chairmen

Clyde E. Williams, 1948–1949

Edgar H. Dix, Jr., 1950–1953

Leo Schapiro, 1954–1957

John C. McDonald, 1958

Remarks

Succeeded the Subcommittee on Aircraft Metals (1920–1947) and the Subcommittee on Woods and Plastics for Aircraft (1944–1947).

FLUID MECHANICS, 1949–1958
Subcommittee of
Aerodynamics
Chairmen
Clark B. Millikan, 1949–1955
William R. Sears, 1956–1958

ENGINE PERFORMANCE AND OPERATION, 1951–1958
Subcommittee of
Power Plants for Aircraft
Chairmen
Arnold H. Redding, 1951–1953
Perry W. Pratt, 1954–1957
Don L. Walter, 1958

ROCKET ENGINES, 1951–1958
Subcommittee of
Power Plants for Aircraft
Chairmen
Maurice J. Zucrow, 1951–1953
Thomas E. Myers, 1954–1956
Chandler C. Ross, 1957–1958

AIRCRAFT NOISE, 1952–1958
Subcommittee of
Operating Problems
Chairman
William Littlewood, 1952–1958

POWER PLANT CONTROLS, 1952–1958
Subcommittee of
Power Plants for Aircraft
Chairmen
Martin A. Edwards, 1952–1954
Rudolph Bodemuller, 1955–1957
C. Stark Draper, 1958

FLIGHT SAFETY, 1955–1958
Subcommittee of
Operating Problems
Chairman
Charles Froesch, 1955–1958
Remarks
Took over functions of the former Subcommittee on Aircraft Fire Prevention.

AUTOMATIC STABILIZATION AND CONTROL, 1956–1958
Subcommittee of
Aerodynamics
Chairman
Warren E. Swanson, 1956–1958

Table B–6
Chronological List of NACA Special Committees

ENGINEERING PROBLEMS, 1917
Chairman
William F. Durand

PERSONNEL, 1918
Chairman
Joseph S. Ames
Remarks
Succeeded by the Committee on Personnel, Buildings, and Equipment (1919–1941).

DESIGN OF ARMY SEMIRIGID AIRSHIP RS–1, 1923–1925
Chairman
Henry Goldmark

DESIGN OF NAVY RIGID AIRSHIP ZR–1, 1923
Chairman
Henry Goldmark

ENCOURAGEMENT AND REGULATION OF AIRCRAFT IN COMMERCE, 1926
Chairman
William F. Durand

PATENTS AND DESIGN BOARD, 1926
Chairman
David W. Taylor

AERONAUTICAL RESEARCH IN EDUCATIONAL INSTITUTIONS, 1935
Chairman
William R. Gregg

FUTURE RESEARCH FACILITIES, 1938–1939
Chairman
Arthur B. Cook

RELATION OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS TO NATIONAL DEFENSE IN TIME OF WAR, 1938
Chairman
Oscar C. Westover

AERONAUTICAL RESEARCH FACILITIES, 1939
Chairman
Charles A. Lindbergh
Remarks
Entitled Special Survey Committee.

ENGINE RESEARCH FACILITIES, 1939-1940
Chairman
George J. Mead

SITE FOR NEW ENGINE-RESEARCH FACILITY, 1940
Chairman
Vannevar Bush

SITE INSPECTION (FOR NEW ENGINE-RESEARCH FACILITY), 1940
Chairman
John F. Victory

JET PROPULSION, 1941-1943
Chairman
William F. Durand
Remarks
Was a committee in 1942; became a subcommittee of Power Plants in 1944.

MATERIALS RESEARCH COORDINATION, 1944-1946
Chairmen
George W. Lewis, 1944-1945
Russell G. Robinson, 1946

SELF-PROPELLED GUIDED MISSILES, 1945-1947
Chairman
Hugh L. Dryden

SURPLUS AIRCRAFT RESEARCH, 1946
Chairman
Theodore P. Wright

PROCEDURES FOR UNITARY FACILITIES, 1954
Chairman
Hugh L. Dryden

SPACE TECHNOLOGY, 1958
Chairman
H. Guyford Stever
Remarks
The Stever Committee, as it was called, had the following subcommittees and chairmen:
Space Research Objectives, James A. Van Allen
Vehicular Program, Wernher von Braun
Reentry, Milton O. Clauser
Range, Launch, and Tracking Facilities, James R. Dempsey
Instrumentation, William H. Pickering
Space Surveillance, Hendrick W. Bode
Human Factors and Training, W. Randolph Lovelace

Table B-7
Chronological List of NACA Special Subcommittees

AERODYNAMIC PROBLEMS OF TRANSPORT CONSTRUCTION AND OPERATION, 1936
Subcommittee of
Aerodynamics
Chairman
Edward P. Warner

VIBRATION AND FLUTTER, 1936, 1938–1939
Subcommittee of
Aerodynamics
Chairman
Henry J. E. Reid
Remarks
Became a standing subcommittee in 1940.

LIGHTNING HAZARDS TO AIRCRAFT, 1938–1941, 1943–1944
Subcommittee of
Aerodynamics
Chairman
Delbert M. Little
Remarks
Became a standing subcommittee in 1942 and 1945.

TO DIRECT RESEARCH IN APPLIED STRUCTURES, 1938–1941
Subcommittee of
Aircraft Construction
Chairmen
L. M. Grant, 1938–1939
Robert S. Hatcher, 1940–1941

TO MAKE SURVEY OF TECHNIQUES AND EQUIPMENT FOR ELASTIC EXAMINATION OF LARGE AIRCRAFT STRUCTURES IN LIEU OF DESTRUCTION TESTS, 1938–1941
Subcommittee of
Aircraft Construction
Chairman
Richard V. Rhode

SUPERCHARGER COMPRESSORS, 1940–1941
Subcommittee of
Power Plants for Aircraft
Chairman
Val Cronstedt
Remarks
Became a standing subcommittee in 1942.

INDUCTION-SYSTEM DE-ICING, 1940–1941, 1943–1944
Subcommittee of
Power Plants for Aircraft
Chairman
William C. Lawrence
Remarks
Became a standing subcommittee in 1942 and again in 1945.

EXHAUST GAS TURBINES AND INTERCOOLERS, 1940–1941
Subcommittee of
Power Plants for Aircraft
Chairman
Opie Chenoweth
Remarks
Became a standing subcommittee in 1942.

DEICING PROBLEMS, 1941
Subcommittee of
Aerodynamics
Chairman
D. W. Tomlinson
Remarks
Became a standing subcommittee in 1942.

METALS FOR TURBOSUPERCHARGER WHEELS AND BUCKETS, 1941, 1943
Subcommittee of
Aircraft Construction
Chairman
William L. Badger
Remarks
Was a subcommittee in 1942.

WELDING PROBLEMS, 1941, 1943
Subcommittee of
Aircraft Construction
Chairmen
G. F. Jenks, 1941
E. S. Jenkins, 1943
Remarks
Was a subcommittee in 1942.

HEAT-RESISTING ALLOYS, 1944–1946
Subcommittee of
Power Plants for Aircraft
Chairman
William L. Badger
Remarks
Became a standing subcommittee in 1945.

UPPER ATMOSPHERE, 1946-1951

Subcommittee of

Aerodynamics

Chairman

Harry Wexler

RESEARCH PROBLEMS OF TRANSONIC AIRCRAFT DESIGN, 1948

Subcommittee of

Aerodynamics

Chairman

L. E. Root

ROCKET ENGINES, 1951-1954

Subcommittee of

Power Plants for Aircraft

Chairmen

Maurice J. Zucrow, 1951-1953

Thomas E. Myers, 1954

Remarks

Became a standing subcommittee in 1955.

AIRCRAFT NOISE, 1952-1954

Subcommittee of

Operating Problems

Chairman

William Littlewood

Remarks

Became a standing subcommittee in 1955.

Table B–8
Total Committees, by Year

C, committees; SC, subcommittees; SpC, special committees; SpSC, special subcommittees

	C	SC	SpC	SpSC
1915	0	0	0	0
1916	2	8	0	0
1917	2	16	1	0
1918	2	14	0	0
1919	6	0	0	0
1920	6	3	0	0
1921	6	3	0	0
1922	6	0	0	0
1923	6	3	2	0
1924	6	3	1	0
1925	6	3	1	0
1926	6	3	2	0
1927	7	5	0	0
1928	9	9	0	0
1929	9	9	0	0
1930	9	9	0	0
1931	9	9	0	0
1932	8	8	0	0
1933	8	8	0	0
1934	8	8	0	0
1935	8	10	1	0
1936	7	9	0	2
1937	8	6	0	0
1938	8	6	2	4
1939	7	6	3	4
1940	7	9	3	6
1941	7	8	1	9
1942	6	18	0	0
1943	5	13	1	4
1944	4	15	1	3
1945	5	19	2	0
1946	5	21	3	1
1947	5	19	1	1
1948	5	20	0	2
1949	5	21	0	1
1950	5	21	0	1
1951	5	20	0	2
1952	5	21	0	2
1953	5	21	0	2
1954	5	21	1	2
1955	5	23	0	0
1956	5	24	0	0
1957	5	24	0	0
1958	5	23	1	0

Table B–9
Technical Committee Memberships by Decade, 1918–1958

Technical Committee Membership, 1918

Affiliation*	Total	C**	SC	SpC	SpSC
NACA, Committee	33	29 (88%)	4 (12%)	...	...
	(40%)	(56%)	(14%)	...	...
NACA, Staff	4	3 (75%)	1 (25%)	...	...
	(5%)	(6%)	(3%)	...	...
Government, Military	18	13 (72%)	5 (28%)	...	...
	(22%)	(25%)	(17%)	...	...
Government, Civilian	13	5 (38%)	8 (62%)	...	...
	(16%)	(10%)	(28%)	...	...
Private, Industry	9	1 (11%)	8 (89%)	...	...
	(11%)	(2%)	(28%)	...	...
Private, Other	4	1 (25%)	3 (75%)	...	...
	(5%)	(2%)	(10%)	...	...
	81	52 (66%)	29 (34%)	...	...
	Chairmanships				
NC	14	11 (79%)	3 (21%)	...	...
NS	1	...	1 (100%)	...	...
GM	1	...	1 (100%)	...	...
GC	...	...	...	...	...
PI	...	...	...	...	...
PO	...	...	...	...	...
	16	11 (69%)	5 (31%)	...	...

*Affiliations of two members could not be determined.
**For purposes of this table only, the definition of committees and subcommittees is that given in the *Annual Report* for 1918.

Technical Committee Membership, 1928

Affiliation	Total	C	SC	SpC	SpSC
NACA, Committee	21	18 (86%)	3 (14%)	...	...
	(15%)	(25%)	(5%)	...	...
NACA, Staff	25	12 (48%)	13 (52%)	...	...
	(17%)	(17%)	(23%)	...	...
Government, Military	29	17 (59%)	12 (41%)	...	...
	(20%)	(24%)	(21%)	...	...
Government, Civilian	31	11 (35%)	20 (57%)	...	...
	(22%)	(15%)	(36%)	...	...
Private, Industry	19	6 (32%)	13 (68%)	...	...
	(13%)	(8%)	(23%)	...	...
Private, Other	18	8 (44%)	10 (56%)	...	...
	(13%)	(11%)	(18%)	...	...
	143	72 (50%)	71 (50%)	...	...

Affiliation	Total	C	SC	SpC	SpSC
	Chairmanships				
NC	11	9 (100%)	2 (22%)		
NS	1		1 (11%)		
GM	1		1 (11%)		
GC	3		1 (11%)		
PI	1		1 (11%)		
PO	1				
	18	9	6		

Technical Committee Membership, 1938

Affiliation	Total	C	SC	SpC	SpSC
NACA, Committee	26	16 (62%)	3 (12%)	7 (27%)	
	(15%)	(20%)	(5%)	(88%)	
NACA, Staff	33	14 (42%)	10 (30%)	1 (3%)	8 (24%)
	(19%)	(18%)	(19%)	(12%)	(24%)
Government, Military	50	22 (44%)	17 (34%)		11 (22%)
	(29%)	(30%)	(31%)		(33%)
Government, Civilian	47	20 (43%)	17 (36%)		10 (21%)
	(27%)	(25%)	(31%)		(30%)
Private, Industry	16	8 (50%)	5 (32%)		3 (19%)
Private, Other	3		2 (67%)		1 (33%)
	(2%)		(4%)		(3%)
	175	80 (46%)	54 (31%)	8 (5%)	33 (19%)
	Chairmanships				
NC	11	8 (100%)	3 (50%)	2 (100%)	
NS	2				2 (50%)
GM	1				1 (25%)
GC	4		3 (50%)		1 (25%)
PI					
PO	0				
	20	8	6	2	4

Technical Committee Membership, 1948

Affiliation	Total	C	SC	SpC	SpSC
NACA, Committee	1	1(100%)			
	(–)	(1%)			
NACA, Staff	55	12 (22%)	39 (71%)		4 (7%)
	(14%)	(15%)	(14%)		(11%)
Government, Military	91	15 (16%)	67 (74%)		9 (10%)
	(24%)	(19%)	(25%)		(26%)
Government, Civilian	37	6 (16%)	29 (78%)		2 (5%)
	(10%)	(8%)	(11%)		(6%)

Affiliation	Total	C	SC	SpC	SpSC
Private, Industry	154	34 (22%)	105 (68%)		15 (10%)
	(40%)	(44%)	(39%)		(43%)
Private, Other	46	10 (22%)	31 (67%)		5 (11%)
	(12%)	(13%)	(11%)		(14%)
	384	78 (20%)	271 (71%)	0	35 (9%)
	Chairmanships				
NC	1		1 (5%)		
NS	4		4 (20%)		
GM	1		1 (5%)		
GC	1				1 (50%)
PI	16	4 (80%)	11 (55%)		1 (50%)
PO	4	1 (20%)	3 (15%)		
	27	5	20		2

Technical Committee Membership, 1958

Affiliation	Total	C	SC	SpC	SpSC
NACA, Committee	2	1 (50%)	1 (50%)		
	(–)	(1%)	(–)		
NACA, Staff	112	16 (14%)	77 (69%)	5 (4%)	14 (13%)
	(17%)	(15%)	(15%)	(28%)	(21%)
Government, Military	147	20 (14%)	110 (75%)	3 (2%)	14 (10%)
	(23%)	(19%)	(24%)	(17%)	(21%)
Government, Civilian	32	6 (19%)	26 (81%)		
	(5%)	(6%)	(6%)		
Private, Industry	288	53 (18%)	204 (71%)	5 (2%)	26 (9%)
	(44%)	(50%)	(44%)	(28%)	(39%)
Private, Other	71	11 (15%)	42 (59%)	5 (7%)	13 (18%)
	(11%)	(10%)	(9%)	(28%)	(19%)
	652	107 (16%)	460 (71%)	18 (3%)	67 (10%)
	Chairmanships				
NC	1		1 (4%)		
NS	0				
GM	1				1 (14%)
GC	0				
PI	24	5 (100%)	16 (70%)		3 (43%)
PO	10		6 (26%)	1 (100%)	3 (43%)
	36	5	23	1	7

Appendix C
Budget

The NACA received its funding from two sources: direct congressional appropriations, and transfers from other government agencies. By far the most important was the congressional appropriation. Table C–1 lists all major NACA appropriations by the fiscal year for which the funds were appropriated. Note that the appropriating legislation may have passed well before or after the year for which the funds were intended. For the sake of simplicity, four classes of appropriations have been excluded from this table:

(1) Deficiency-act appropriations for certified claims of less than $1,000. These were generally for accident damage or unpaid balances on contracts. When money was appropriated to the NACA for such purposes, the legislation is listed under the appropriate fiscal year and the sum entered in brackets. Bracketed figures are not included in the total appropriation.

(2) Special appropriations for NACA participation in fairs and expositions like the Chicago World's Fair of 1933.

(3) Foreign-service adjustment pay for John J. Ide and his staff in the Paris office.

(4) Several general-appropriation acts were applicable to all government agencies. For example, the Legislative Acts of 1919, 1920, and 1921 are not listed. Each provided a pay raise for government employees, but the total amount going to the NACA has not been determined. The pay raises of 1923 and 1924 are included because the amount received by the NACA is known.

The figures in Table C–1 may vary from those reported by the NACA. There are several reasons for this: When funds were appropriated for two years, the table will list them under the first year, while the NACA would report them under the second. Some appropriations were modified retroactively and the NACA did not always adjust its records. Finally, the NACA reported only its major direct appropriations, not the smaller deficiency acts.

The first graph traces total NACA appropriations throughout the Committee's history. Plotting the entire record on a single scale reduces the first half of the story to virtually a straight line of indeterminate slope; more money was appropriated to the NACA in 1943 than in its entire first 25 years combined. The changes wrought by World War II are nowhere more dramatically revealed than in this chart.

Table C–2 divides NACA annual appropriations into general-purpose and construction categories. The figures are somewhat misleading, for (as George Lewis observed in 1940) "under 'General Purposes' are listed items of permanent equipment, such as a new wind-tunnel balance or an engine dynamometer set-up." He concluded that "it would be difficult to break down what is actually spent on research equipment and construction," * and no attempt has been made here to second-guess the NACA estimates of which was which. For all their imprecision, these figures are a fair approximation of what the NACA and the Congress intended to be the Committee's major acquisition, construction, and renovation expenses.

The second graph presents the Committee's appropriations, general-purpose and construction, in two parts: one for 1915–1935, one for 1936–1959. Note the drastic change in scale: the appropriation for 1936, which begins part II of the chart, was at the time the largest in the Committee's history.

*Lewis to J. C. Hunsaker, 3 March 1940.

During most of its history the NACA considered its organic act of 1915 to be authorizing legislation. Generally, NACA requests for funds went directly to the appropriations committees of each house of Congress without the formality of an authorization act. There were two exceptions to this rule. In World War I the NACA was considered part of the Navy for budget purposes; it received its funds through the Naval Acts for fiscal years 1916 through 1918. These were authorized funds, approved by the military affairs committees of each house before going to appropriations committees. In 1917 the Comptroller General determined that the NACA was an independent agency. Its fiscal-year 1919 budget, and all those thereafter, were included in the Sundry Civil Act (1919–1922) or the Executive and Independent Offices Act (1923–1959). In the early 1950s, some congressmen came to believe that NACA budgets were too large to be appropriated without specific authorization. The resulting authorizing acts—listed in Table C–3—were mostly for construction.

Some legislation over the years set limits on how the NACA might spend its appropriations. For example, the Deficiency Act for War Expenses of 28 March 1918 raised the limit on rent paid for office spaces from $1500 to $2332. Most of these restrictions were included in the NACA's appropriations acts. Some legislation allowed transfer of funds from one NACA account to another: e.g., the Second Deficiency Act of 4 March 1931 allowed the transfer of $700 from general expenses to printing and binding.

In every year after establishment of the Bureau of the Budget in 1922, the NACA engaged in the same budget cycle as the other branches of the federal government. Generally it submitted to the Bureau of the Budget in the late summer its request for funds for the fiscal year beginning the following July. Early in the fall, generally after a formal meeting between the chairman of the NACA and the director of BoB, a budget figure was recommended to the president. The figure he approved was submitted to Congress by BoB. The following spring or summer, Congress would enact the appropriation, raising or lowering the requested figure as it saw fit. The same procedure was followed when the NACA needed supplemental appropriations.

From time to time the NACA received funds from other government agencies. In the early 1920s, the army and navy transferred funds to the NACA to pay for research services; thereafter, the NACA included such funds in its own budget requests. The moneys later transferred to the NACA by the military were for construction. The Committee in turn transferred funds to other federal agencies that performed research at the NACA's request. Most of this money went to the National Bureau of Standards. Table C–4 lists interagency transfers for which Treasury Department warrants appear in the NACA files. Over the years, other occasional transfers took place but there is no systematic record of them.

Table C–5 lists NACA expenditures by fiscal year. If the Committee appears to have spent more in a fiscal year than was appropriated to it, the reason is that it was spending the remainder of a two-year or multiyear appropriation. Note that the NACA often returned considerable sums to the Treasury at the end of the fiscal year. Table C–6 shows distribution of expenditures among the different NACA branches after 1940. Before that time, when the NACA consisted only of the headquarters and the Langley laboratory, the ratio of their expenditures was about one to eight respectively.

An important question in the history of the NACA is the proportion of U.S. aeronautical research conducted by the Committee after World War II. Reliable figures are hard to come by, but Table C–7 provides one estimate that seems fairly accurate. The "Federal Non-Defense" category represents almost entirely the NACA. Table C–8 divides the federal portion of these figures into categories of "Research and Technology" and "Development." Note that approximately two thirds of the nondefense funding was for development.

Table C-1
NACA Appropriations, by Year

1915	
Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)	$5,000.00
1916	
Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)	5,000.00
1917	
Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)	5,000.00
Naval Act, 1917 (P.L. 241, 64/1, 29 Aug. 1916)	82,515.70
	87,515.70
1918	
Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)	5,000.00
Naval Act, 1918 (P.L. 391, 64/2, 4 March 1917)	107,000.00
	112,000.00
1919	
Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)	5,000.00
Sundry Civil Act, 1919 (P.L. 181, 65/2, 1 July 1918)	200,000.00
	205,000.00
1920	
Sundry Civil Act, 1920 (P.L. 21, 66/1, 19 July 1919)	175,000.00
1921	
Sundry Civil Act, 1921 (P.L. 246, 66/2, 5 June 1920)	200,000.00
1922	
Sundry Civil Act, 1922 (P.L. 389, 66/3, 4 March 1921)	200,000.00
1923	
Executive and Independent Establishments Appropriations, 1923 (P.L. 240, 67/2, 12 June 1922)	210,000.00
Additional Compensation Act (P.L. 257, 67/2, 29 June 1922)	15,600.00
Deficiency Act (P.L. 385, 67/4, 22 January 1923)	[105.03]
Second Deficiency Act (P.L. 1035, 70/2, 4 March 1929)	[258.17]
	225,600.00
1924	
Executive and Independent Establishments Appropriations, 1924 (P.L. 409, 67/4, 13 February 1923)	283,000.00
Additional Compensation Act (P.L. 544, 67/4, 4 March 1923)	24,000.00
Deficiency Act (P.L. 66, 68/1, 2 April 1924)	[63.48]
	307,000.00

1925

Executive and Independent Establishments Appropriations, 1925 (P.L. 214, 68/1, 7 June 1924)	440,000.00
Field Service Compensation Act (P.L. 293, 68/2, 6 December 1924)	30,000.00
	470,000.00

1926

Executive and Independent Establishments Appropriations, 1926 (P.L. 586, 68/2, 3 March 1925)	534,000.00
First Deficiency Act, 1926 (P.L. 36, 64/1, 3 March 1926)	[2.67]
	534,000.00

1927

Executive and Independent Establishments Appropriations, 1927 (P.L. 141, 69/1, 22 April 1926)	513,000.00
First Deficiency Act, 1927 (P.L. 660, 69/2, 28 February 1927)	[1,018.59]
	513,000.00

1928

Independent Offices Act, 1928 (P.L. 600, 69/2, 11 February 1927)	525,000.00
Deficiency Act, 1928 (P.L. 2, 70/1, 22 December 1927)	25,000.00
	[.83]
	550,000.00

1929

Independent Offices Act, 1929 (P.L. 400, 70/1, 16 May 1928)	600,000.00
First Deficiency Act, 1929 (P.L. 1034, 70/2, 4 March 1929)	[1.18]
Second Deficiency Act, 1929 (P.L. 1035, 70/2, 4 March 1929)	236,770.00
Second Deficiency Act, 1933 (P.L. 442, 72/2, 4 March 1933)	[605.12]
	836,770.00

1930

Independent Offices Act, 1930 (P.L. 778, 70/2, 20 Feb. 1929)	1,292,200.00
(Unexpended funds, 1928)	7,800.00
	1,300,000.00

1931

Independent Offices Act, 1931 (P.L. 158, 71/2, 19 April 1930)	1,321,000.00

1932

Independent Offices Appropriation Act, 1932 (P.L. 720, 71/3, 23 February 1931)	1,051,070.00

1933

Independent Offices Appropriation Act, 1933 (P.L. 228, 72/1, 30 June 1932)	920,000.00

1934

Independent Offices Appropriation Act, 1934 (P.L. 78, 73/1, 16 June 1933)	695,000.00
Emergency Appropriation Act, 1935 (P.L. 412, 73/2, 19 June 1934)	7,796.86
National Industrial Recovery Act (P.L. 67, 73/1, 16 June 1933)	247,944.00
5 percent compensation restoration (provided in EIO Act, 1935)	2,904.20
	953,645.06

1935

Independent Offices Appropriation Act, 1935 (P.L. 141, 73/2, 28 March 1934)	726,492.00
National Industrial Recovery Act (P.L. 67, 73/1, 16 June 1933)	478,300.00
5 percent compensation restoration (provided in EIO Act, 1934)	50,986.93
	1,255,778.93

1936

Independent Offices Appropriation Act, 1936 (P.L. 2, 74/1, 2 February 1935)	839,500.00
Second Deficiency Act, 1935 (P.L. 260, 74/1, 12 August 1935)	338,050.00
Emergency Relief Appropriation Act (P.L. 11, 74/1, 8 April 1935)	−660.65
First Deficiency Appropriation Act, 1936 (P.L. 739, 74/2, 22 June 1936)	1,367,000.00
	2,543,889.35

1937

Independent Offices Appropriation Act, 1937 (P.L. 479, 74/2, 19 March 1936)	1,177,550.00
Second Deficiency Appropriation Act, 1937 (P.L. 121, 75/1, 28 May 1937)	453,000.00
	1,630,550.00

1938

Independent Offices Appropriation Act, 1938 (P.L. 171, 75/1, 28 June 1937)	1,280,850.00
First Deficiency Appropriation Act, 1938 (P.L. 440, 75/3, 5 March 1938)	[235.38]
	1,280,850.00

1939

Independent Offices Appropriation Act, 1939 (P.L. 534, 75/3, 23 May 1938)	1,700,000.00
Second Deficiency Appropriation Act, 1939 (P.L. 61, 76/1, 2 May 1939)	2,363,980.00
	4,063,980.00

1940

Independent Offices Appropriation Act, 1940 (P.L. 8, 76/1, 16 March 1939)	2,180,000.00

Third Deficiency Appropriation Act, 1939 (P.L. 361, 76/1, 9 August 1939)	2,000,000.00
First Deficiency Appropriation Act, 1940 (P.L. 447, 76/3, 6 April 1940)	[117.60]

1941

Independent Offices Appropriation Act, 1941 (P.L. 459, 76/3, 18 April 1940)	8,000,000.00
Civil Activities National Defense Appropriation Act, 1941 (P.L. 667, 76/3, 26 June 1940)	3,200,000.00
	11,200,000.00

1942

Independent Offices Appropriation Act, 1942 (P.L. 28, 77/1, 5 April 1941)	13,601,910.00
Second Deficiency Appropriation Act, 1941 (P.L. 150, 77/1, 3 July 1941)	1,340,000.00
Second Supplemental National Defense Appropriation Act, 1942 (P.L. 282, 77/1, 28 October 1941)	1,424,000.00
Sixth Supplemental National Defense Appropriation Act, 1942 (P.L. 528, 77/2, 28 April 1942)	3,500,000.00
	19,865,910.00

1943

Independent Offices Appropriation Act, 1943 (P.L. 630, 77/2, 27 June 1942)	19,082,736.00
First Deficiency Appropriation Act, 1943 (P.L. 11, 78/1, 18 March 1943)	5,494,000.00
Second Deficiency Appropriation Act, 1943 (P.L. 140, 78/1, 12 July 1943)	[245.78]
Urgent Deficiency Appropriation Act, 1943 (P.L. 132, 78/1, 12 July 1943)	852,000.00
	25,428,736.00

1944

Independent Offices Appropriation Act, 1944 (P.L. 90, 78/1, 26 June 1943)	19,454,500.00
First Supplemental National Defense Appropriation Act, 1944 (P.L. 216, 78/1, 23 December 1943)	17,287,715.00
First Deficiency Appropriation Act, 1944 (P.L. 279, 78/2, 1 April 1944)	1,650,000.00 [66.01]
Second Deficiency Appropriation Act, 1944 (P.L. 375, 78/2, 28 June 1944)	[69.75]
	38,392,215.00

1945

Independent Offices Appropriation Act, 1945 (P.L. 358, 78/2, 27 June 1944)	23,233,830.00
First Supplemental Appropriation Act, 1945 (P.L. 529, 78/2, 22 December 1944)	7,401,000.00 [136.00]
First Deficiency Appropriation Act, 1945 (P.L. 40, 79/1, 25 April 1945)	10,307,500.00 [47.50]
Second Deficiency Appropriation Act, 1945 (P.L. 132, 79/1, 5 July 1945)	[21.75]
	40,942,330.00

1946

Independent Offices Appropriation Act, 1946 (P.L. 49, 79/1, 3 May 1945)	26,014,393.00
First Supplemental Surplus Appropriation Rescission Act, 1946 (P.L. 301, 79/2, 18 February 1946)	−2,000,000.00
First Deficiency Appropriation Act, 1946 (P.L. 269, 79/1, 28 December 1945)	[97.84]
Second Deficiency Appropriation Act, 1946 (P.L. 384, 79/2, 18 May 1946)	[28.06]
Legislative, Executive, and Judicial Appropriation Act, 1875 (18 Stat. 110, 20 June 1874)	37,267.63
	24,051,660.63

1947

Independent Offices Appropriation Act, 1947 (P.L. 334, 79/2, 28 March 1946)	29,673,000.00
Deficiency Appropriations, 1947 (P.L. 25, 80/1, 29 March 1947)	1,040,000.00
	30,713,000.00

1948

Independent Offices Appropriation Act, 1948 (P.L. 264, 80/1, 30 July 1947)	43,449,000.00

1949

Independent Offices Appropriation Act, 1949 (P.L. 491, 80/2, 20 April 1948)	47,905,000.00
Second Deficiency Appropriation Act, 1949 (P.L. 119, 81/1, 23 June 1949)	747,000.00
	48,652,000.00

1950

Independent Offices Appropriation Act, 1950 (P.L. 266, 81/1, 24 August 1949)	53,000,000.00
Deficiency Appropriation Act, 1950 (P.L. 583, 81/2, 29 June 1950)	75,000,000.00
	128,000,000.00

1951

General Appropriation Act, 1951 (P.L. 759, 81/2, 6 September 1950)	58,000,000.00

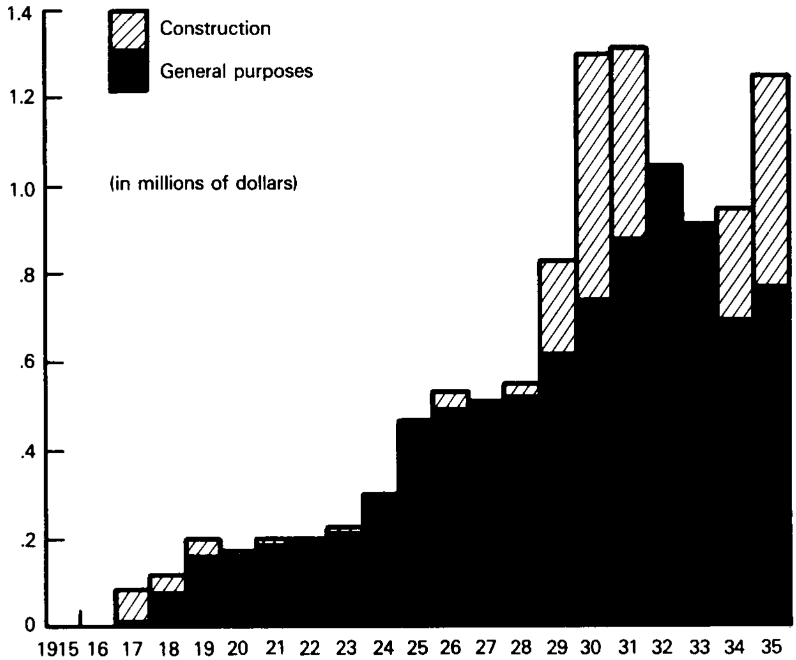
Second Supplemental Appropriation Act, 1951 (P.L. 911, 81/2, 6 January 1951)	5,068,000.00
	63,068,000.00
1952	
Independent Offices Appropriation Act, 1952 (P.L. 137, 82/1, 31 August 1951)	67,600,000.00
Third Supplemental Appropriation Act, 1952 (P.L. 375, 82/2, 5 June 1952)	1,400,000.00
	69,000,000.00
1953	
Independent Offices Appropriation Act, 1953 (P.L. 455, 82/2, 5 July 1952)	66,286,100.00
1954	
First Independent Offices Appropriation Act, 1954 (P.L. 176, 83/1, 31 July 1953)	62,439,000.00
1955	
Independent Offices Appropriation Act, 1955 (P.L. 428, 83/2, 24 June 1954)	55,620,000.00
Second Supplemental Appropriation Act, 1955 (P.L. 24, 84/1, 22 April 1955)	240,000.00
	55,860,000.00
1956	
Independent Offices Appropriation Act, 1956 (P.L. 112, 84/1, 30 June 1955)	72,700,000.00
1957	
Independent Offices Appropriation Act, 1957 (P.L. 623, 84/2, 25 June 1956)	75,887,500.00
Supplemental Appropriation Act, 1957 (P.L. 814, 84/2, 27 July 1956)	789,000.00
	76,676,500.00
1958	
Second Supplemental Appropriation Act, 1959 (P.L. 85-352, 85/1, 28 March 1958)	9,920,000.00
Independent Offices Appropriation Act, 1958 (P.L. 85-69, 85/1, 29 June 1957)	106,000,000.00
Temporary Appropriations, 1959 (P.L. 85-472, 85/2, 30 June 1958)	1,356,209.00
	117,276,209.00
1959	
Independent Offices Appropriation Act, 1959 (P.L. 85-844, 85/2, 28 Aug. 1958)	101,100,000.00

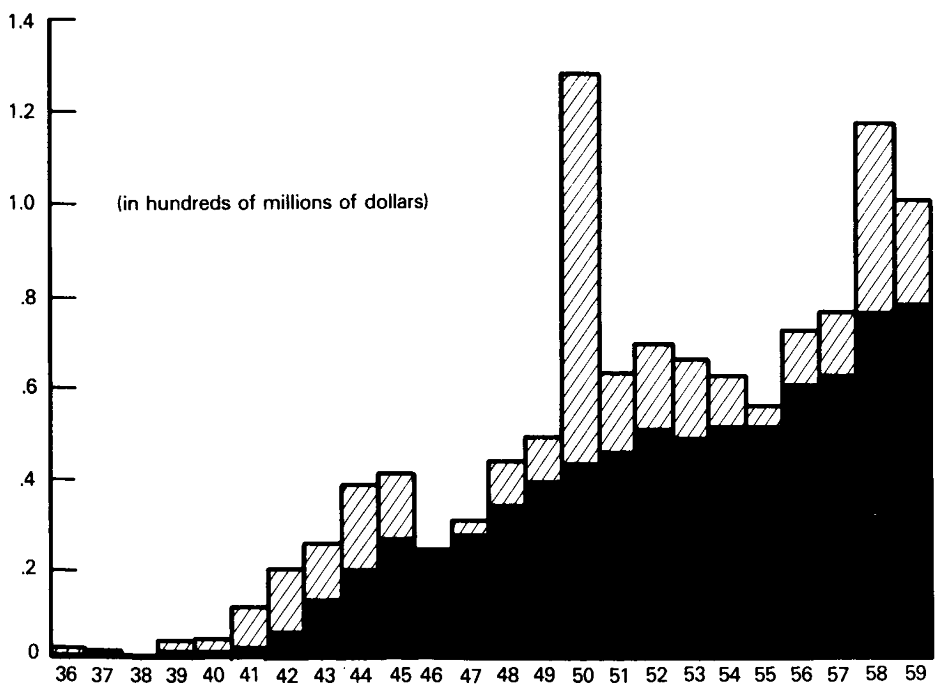
Table C–2
NACA Appropriations, Yearly by Category

	General Purposes	Construction	Total (dollars)
1915	5,000.00	....	5,000.00
1916	5,000.00	....	5,000.00
1917	18,515.70	69,000.00	87,515.70
1918	82,000.00	40,000.00	112,000.00
1919	167,000.00	38,000.00	205,000.00
1920	169,600.00	5,400.00	175,000.00
1921	192,000.00	8,000.00	200,000.00
1922	197,000.00	3,000.00	200,000.00
1923	215,600.00	10,000.00	225,600.00
1924	307,000.00	....	307,000.00
1925	470,000.00	....	470,000.00
1926	494,000.00	40,000.00	534,000.00
1927	513,000.00	....	513,000.00
1928	525,000.00	25,000.00	550,000.00
1929	623,770.00	213,000.00	836,770.00
1930	745,000.00	555,000.00	1,300,000.00
1931	886,000.00	435,000.00	1,321,000.00
1932	1,051,070.00	....	1,051,070.00
1933	920,000.00	....	920,000.00
1934	705,701.06	247,944.00	953,645.06
1935	777,478.93	478,300.00	1,255,778.93
1936	1,176,889.35	1,367,000.00	2,543,889.35
1937	1,277,550.00	453,000.00	1,630,550.00
1938	1,280,850.00	....	1,280,850.00
1939	1,723,980.00	2,340,000.00	4,063,980.00
1940	1,849,020.00	2,330,980.00	4,180,000.00
1941	2,800,000.00	8,400,000.00	11,200,000.00
1942	6,220,465.00	13,645,445.00	19,865,910.00
1943	13,113,736.00	12,315,000.00	25,428,736.00
1944	19,635,415.00	18,756,800.00	38,392,215.00
1945	26,557,330.00	[a] 14,385,000.00	40,942,330.00
1946	24,014,393.00	37,267.63	24,051,660.63
1947	27,615,000.00	[b] 3,098,000.00	30,713,000.00
1948	33,570,000.00	9,879,000.00	43,449,000.00
1949	38,652,000.00	10,000,000.00	48,652,000.00
1950	43,000,000.00	85,000,000.00	128,000,000.00
1951	45,750,000.00	17,318,000.00	63,068,000.00
1952	50,650,000.00	18,350,000.00	69,000,000.00
1953	48,586,100.00	17,700,000.00	66,286,100.00
1954	51,000,000.00	11,439,000.00	62,439,000.00
1955	51,240,000.00	4,620,000.00	55,860,000.00
1956	60,135,000.00	12,565,000.00	72,700,000.00
1957	62,676,500.00	14,000,000.00	76,676,500.00
1958	76,076,209.00	41,200,000.00	117,276,209.00
1959	78,100,000.00	23,000,000.00	101,100,000.00

[a] $4,611,330 transferred from the navy and the Federal Works Admin.
[b] $110,872 transferred from the navy.

NACA Appropriations by Fiscal Year: 1915–1935; 1936–1959





Total NACA Appropriations by Fiscal Year
(in millions of dollars)

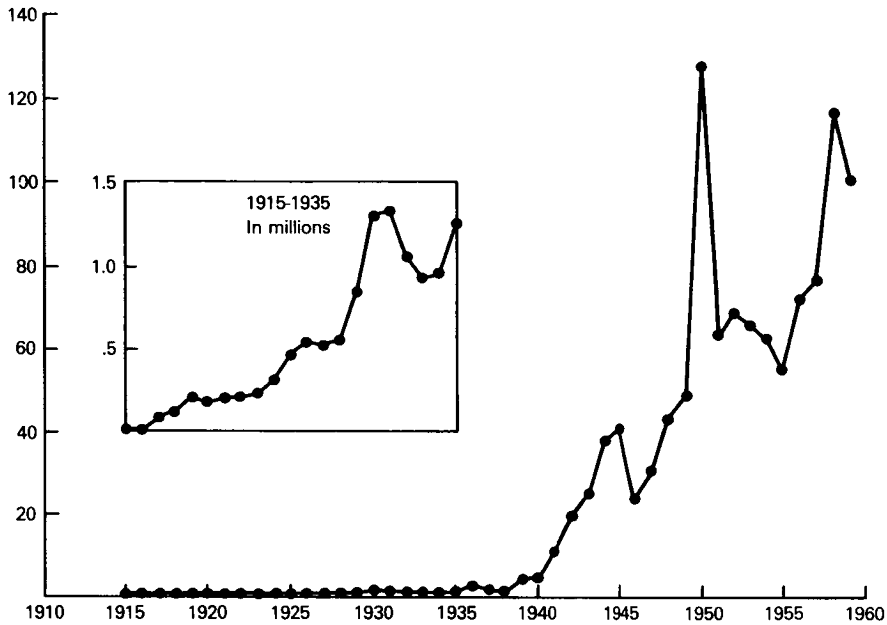


Table C-3
NACA Authorizations

Naval Act, 1916 (P.L. 271, 63/3, 3 March 1915)

This act was interpreted as the general authorizing legislation for all NACA activities. Not until the 1950s was the adequacy of this legislation questioned, specifically for authorizing construction.

(P.L. 672, 81/2, 8 August 1950)

This act authorized $16,500,000 for general purposes for advancing aeronautical research.

(P.L. 403, 82/2, 23 June 1952)

This act authorized construction at Lewis and Langley laboratories totaling $19,700,000.

(P.L. 371, 83/2, 27 May 1954)

This act authorized $5,000,000 for construction and equipment.

(P.L. 44, 84/1, 23 May 1955)

This act authorized $13,300,000 for construction and equipment.

(P.L. 253, 85/1, 2 September 1957)

This act authorized $45,450,000 for construction and equipment.

(P.L. 617, 85/2, 8 August 1958)

This act authorized $29,933,000 for construction and equipment.

Table C–4
Interagency Transfers of Funds

	To the NACA	From the NACA
1921	$73,500 Aviation, Navy	$40,000 Bureau of Standards
1922	$12,000 Air Service, Army	$35,000 Bureau of Standards
....	$79,500 Aviation, Navy	
1923	$43,800 Aviation, Navy	$27,000 Bureau of Standards
....	$15,600 Air Service, Army	
1924	$27,000 Aviation, Navy	$28,000 Bureau of Standards
1925	$11,600 Air Service, Army	$32,000 Bureau of Standards
1926		$32,600 Bureau of Standards
1927		$34,000 Bureau of Standards
....		$2,500 Forest Products Lab
1928		$34,900 Bureau of Standards
....		$2,500 Forest Products Lab
1929		$43,372.15 Bureau of Standards
....		$2,500 Forest Products Lab
1930		$46,000 Bureau of Standards
1931		$51,000 Bureau of Standards
1932		$49,500 Bureau of Standards
....		$360 War Department
1933		$42,400 Bureau of Standards
1935		$5,600 Dept. of Commerce
1936		$36,400 Bureau of Standards
1937		$62,600 Bureau of Standards
1938		$66,871 Bureau of Standards
1939		$68,634 Bureau of Standards
1940		$70,000 Bureau of Standards
1941		$100,000 Bureau of Standards
1942		$100,000 Bureau of Standards
1943	$330,000 Emergency Funds for the President.	$142,300 Bureau of Standards
1944		$131,634 Bureau of Standards
1945	$111,330 Federal Works Agency	$145,300 Bureau of Standards
1946	$4,500,000 Navy*	$127,000 Bureau of Standards
1947	$110,872 Navy*	$107,584 Bureau of Standards

*I find no Treasury Warrants for these funds.

Table C-5
NACA Expenditures, by Fiscal Year

1915	$3,938.94	1937	$1,461,018.65
1916	4,904.28	1938	2,114,460.69
1917	87,515.70	1939	2,228,773.59
1918	112,000.00	1940	3,158,713.06
1919	204,381.27	1941	8,135,846.98
1920	174,296.75	1942	11,785,906.95
1921	199,959.21	1943	23,947,549.88
1922	193,859.26	1944	29,799,387.14
1923	214,151.53	1945	33,191,515.21
1924	286,698.27	1946	32,050,966.52
1925	382,805.96	1947*	35,190,095.00
1926	561,125.88	1948	37,543,270.00
1927	531,142.58	1949	48,682,884.00
1928	535,548.78	1950	54,484,474.00
1929	624,558.88	1951	61,586,792.00
1930	979,691.73	1952	67,396,908.00
1931	1,556,891.00	1953	78,585,105.00
1932	1,105,692.72	1954	89,515,996.00
1933	920,113.94	1955	73,796,890.00
1934	898,428.23	1956	71,099,314.00
1935	1,168,980.50	1957	76,065,305.00
1936	1,261,337.94	1958	83,378,118.00

Source: 1915–1922, 1929, NACA *Annual Report;* 1923–1958, *The Budget.*

*Figures were rounded off to the nearest dollar after 1946.

Table C-6
NACA Expenditures (after 1940), by Subdivision

	HQ	Langley	Ames	Lewis	Wallops	HSFS
1940	$157,946	$1,641,150	$104,020	....	....	....
1941	196,935	2,091,889	229,307	....	....	....
1942	328,979	4,215,736	828,921	$421,798	....	....
1943	371,353	6,002,447	1,604,651	4,559,693	....	....
1944	416,586	7,667,537	2,535,386	7,972,423	....	....
1945	407,806	10,832,226	3,050,071	10,455,750	....	....
1946	764,200	13,616,625	4,921,660	13,930,715	....	....
1947	623,612	11,826,315	3,962,356	12,354,438	....	....
1948	1,392,862	13,694,187	5,134,140	12,708,420	....	....
1949	788,356	15,327,202	6,126,230	14,315,302	$643,376	$326,922
1950	895,124	16,705,748	6,990,932	16,043,756	466,407	685,072
1951	1,081,842	17,631,974	7,535,318	16,416,186	803,904	919,281
1952	1,200,617	19,692,928	8,277,495	18,381,205	777,545	1,208,163
1953	1,137,088	19,261,787	7,794,571	17,292,736	594,371	1,368,065
1954	1,340,524	19,503,862	7,980,951	17,598,976	756,093	1,437,368
1955	1,338,752	20,117,456	8,498,011	18,207,519	687,925	1,705,182
1956	1,541,237	22,083,125	11,269,561	21,996,415	910,217	1,913,134
1957	1,623,981	27,796,270	13,267,350	25,662,580	1,001,005	2,117,607
1958	1,958,201	32,774,912	20,312,089	30,461,848	2,323,465	2,565,353

Source: 1940–1955, *The Budget;* 1956–1958, NACA *Annual Report.*

Table C-7
U.S. Postwar Expenditures for Aeronautical Research
(in millions of dollars)

	Federal Defense	Federal Non-Defense	Industry	Total
1945	311	31	23	365
1946	418	38	28	484
1947	349	31	37	417
1948	362	44	48	454
1949	414	55	70	539
1950	441	60	91	592
1951	684	66	164	914
1952	1,102	116	277	1,495
1953	1,535	79	339	1,953
1954	1,686	56	343	2,085
1955	1,600	48	320	1,968
1956	1,658	52	353	2,063
1957	1,802	51	392	2,245
1958	1,909	60	356	2,325

Source: *R&D Contributions to Aviation Progress,* Vol II, Appendix 9, p. 6. The authors of this study note that "the accuracy of the annual funding data . . . is . . . questionable, but the magnitude of the expenditures and the resulting trends are, probably, about as representative of actual conditions as can be expected to be portrayed." (p.4)

Table C-8
Government Aeronautical R&D Funding, by Type of R&D
(in millions of dollars)

	Research & Technology			Development			
	Fed Def	Non-Def	Total	Def	Non-Def	Total	Total
1945	65	11	76	246	20	266	342
1946	86	13	99	332	25	357	456
1947	75	11	86	274	20	294	380
1948	82	15	97	280	29	309	406
1949	98	19	117	316	36	352	469
1950	113	19	132	328	41	369	501
1951	194	23	217	490	43	533	750
1952	316	40	356	786	76	862	1,218
1953	425	27	452	1,110	52	1,162	1,614
1954	453	19	472	1,233	37	1,270	1,742
1955	431	17	448	1,169	31	1,200	1,648
1956	449	19	468	1,209	33	1,242	1,710
1957	488	19	507	1,314	32	1,346	1,853
1958	499	17	516	1,410	43	1,453	1,969

Source: Same as Table C-7, p. 14.

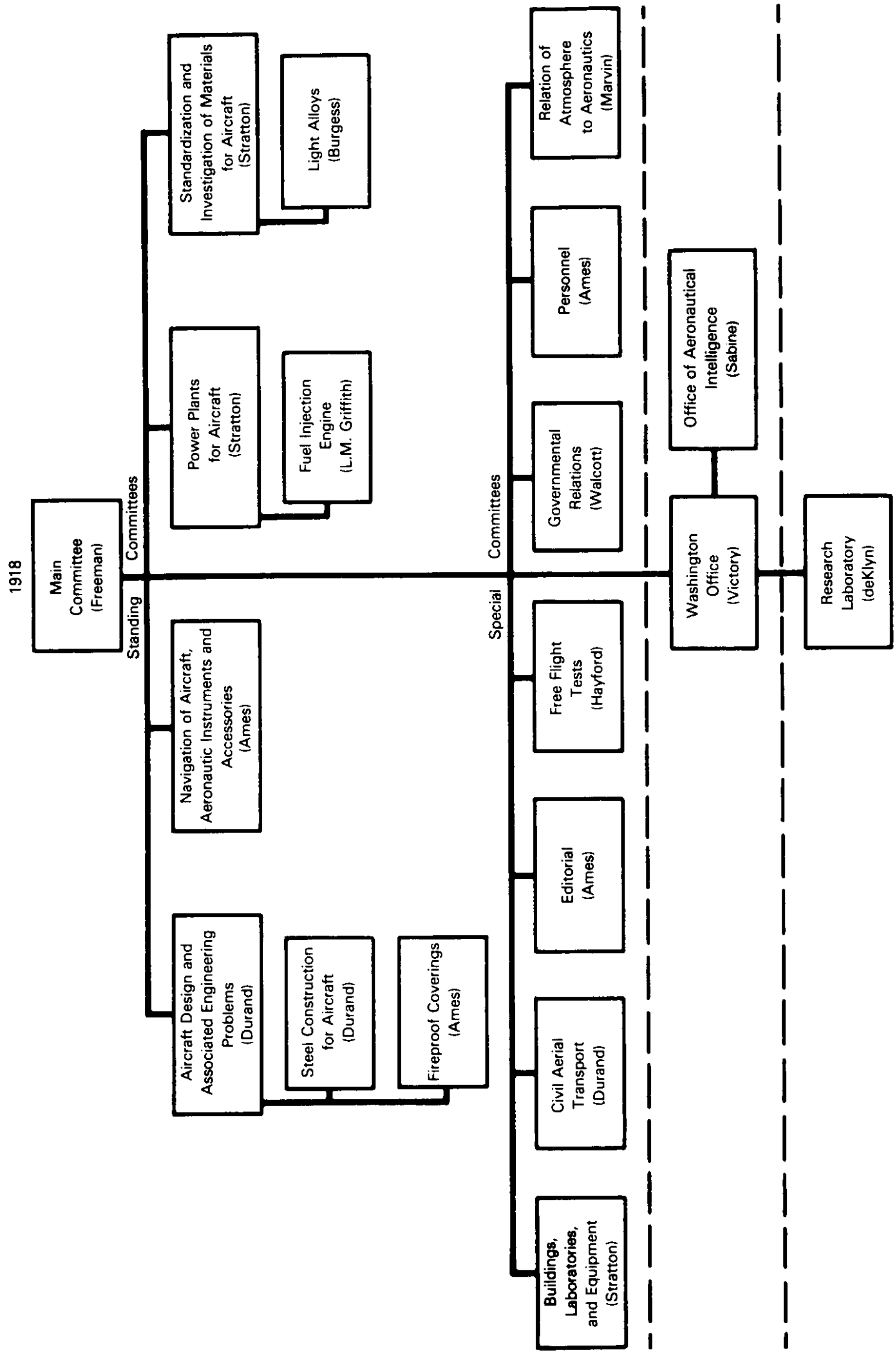
Appendix D
Personnel

Especially for the early years of the NACA, reliable information on its staff is hard to come by. The Committee prided itself on identifying and rewarding highly competent people, but it also insisted on teamwork and on individual willingness to sacrifice for the good of the organization. George Lewis distrusted and eschewed organization charts, which he thought would fragment the staff and impede free exchange of ideas and information across organizational and disciplinary boundaries. As a result, no comprehensive picture of the NACA personnel structure is extant. The following tables contain what fundamental information is available.

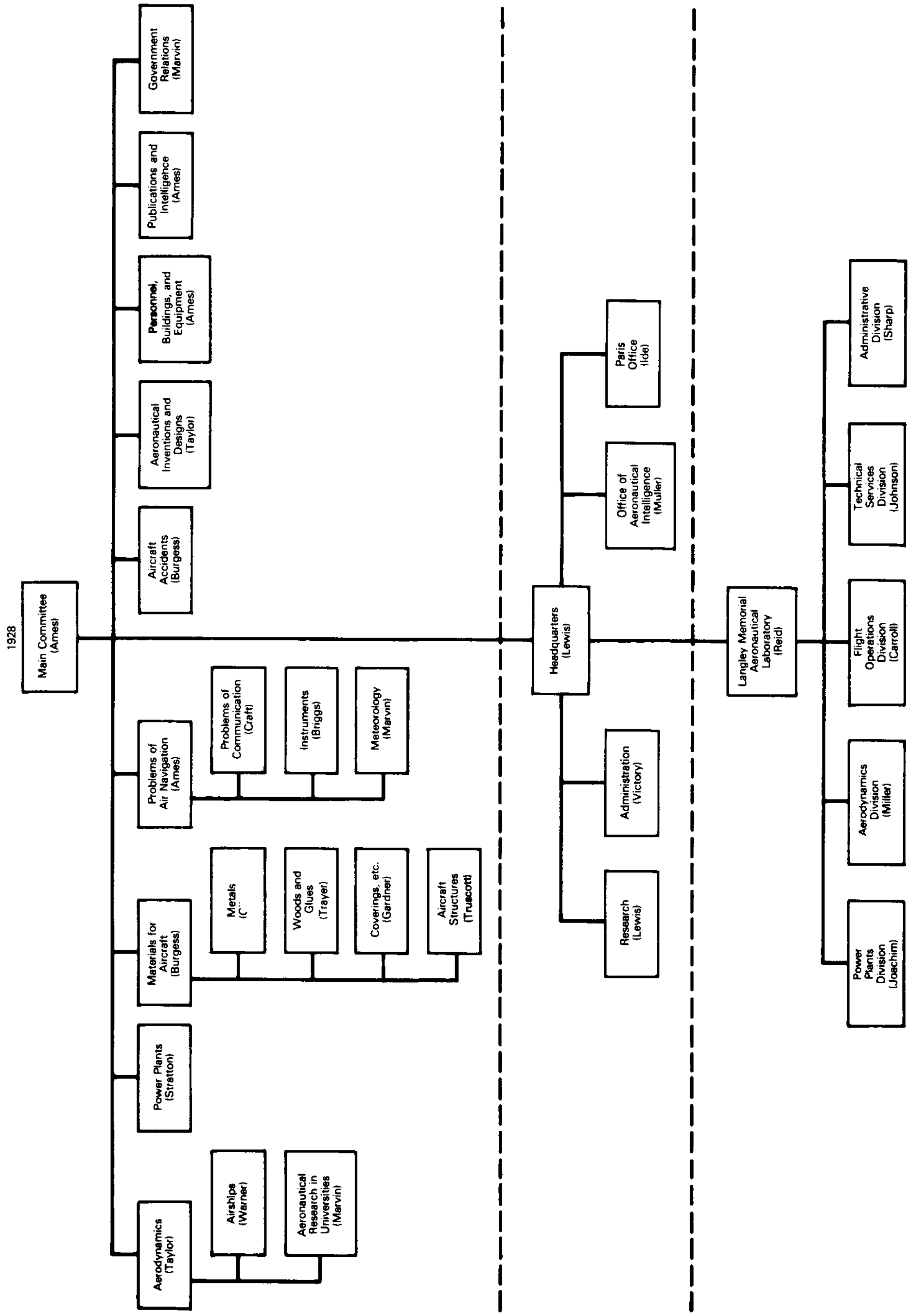
Table D–1 gives total numbers of permanent NACA employees, in headquarters and field categories. For the years 1915–1920 and 1922–1923, these figures are from unpublished NACA sources. Figures for all other years appear in *The Budget* of the United States. Total and average salaries are shown for each year.

Table D–2 lists key positions in the NACA between 1938 and 1958. For each laboratory and station, the key positions in effect at the end of the NACA's life are listed first, giving the various titles of the position and its incumbents. Following these are lists of positions in existence after 1938 but discontinued before 1958. Data in this table come from the annual *Official Register of the United States,* for the years 1938–1958. This source has the advantage of publishing information the NACA seems never to have compiled for itself, but unfortunately did not provide organization charts and was not published before 1937. This table is something of a Who's Who within the NACA, but it does not necessarily include all important members of the staff; for example, Robert T. Jones and Richard T. Whitcomb are conspicuous by their absence.

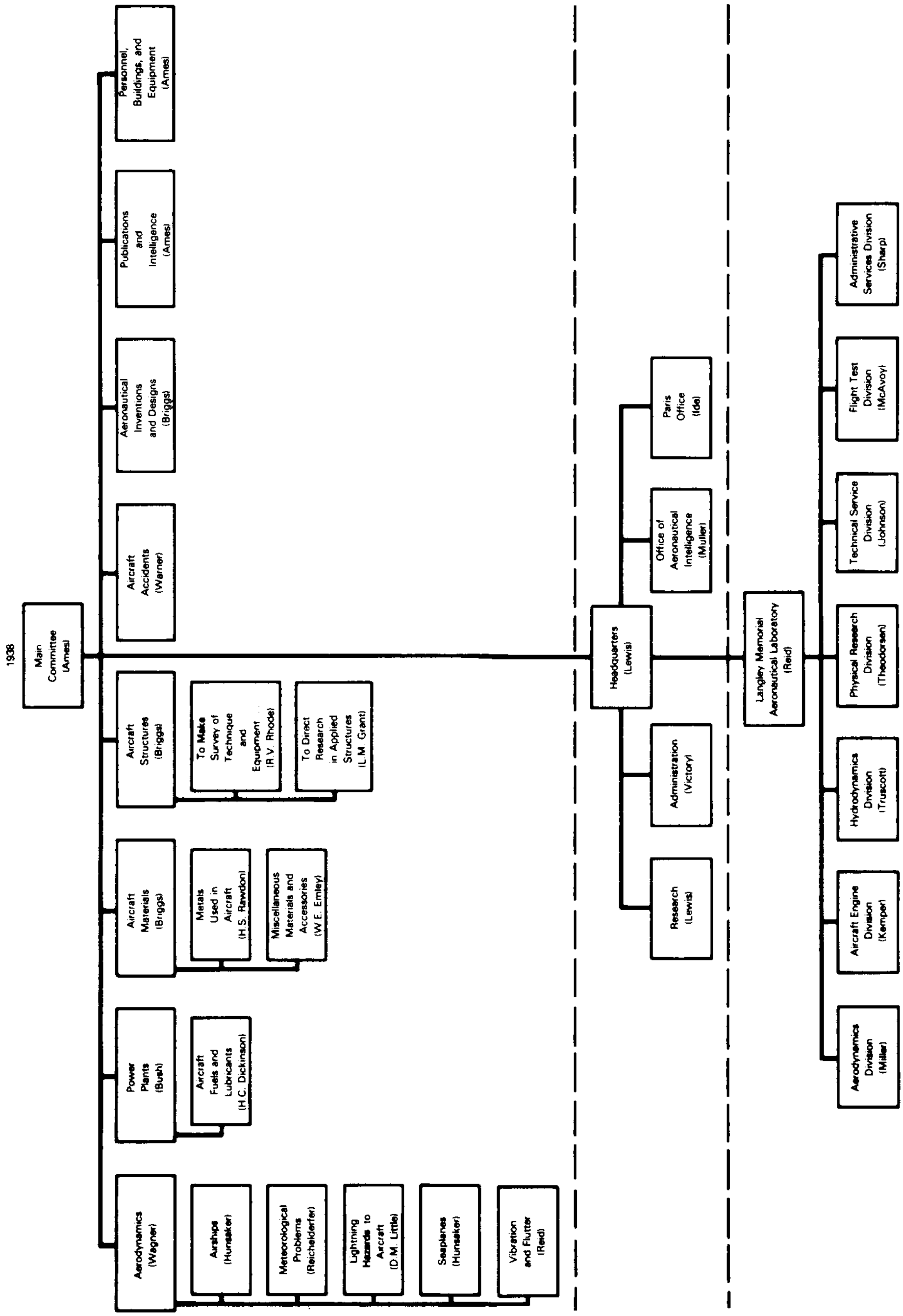
The accompanying hypothetical organization charts for the years 1918, 1928, 1938, 1948, and 1958 represent in most instances the author's guess at how organization charts would have looked had the NACA undertaken to prepare them in August of those years.



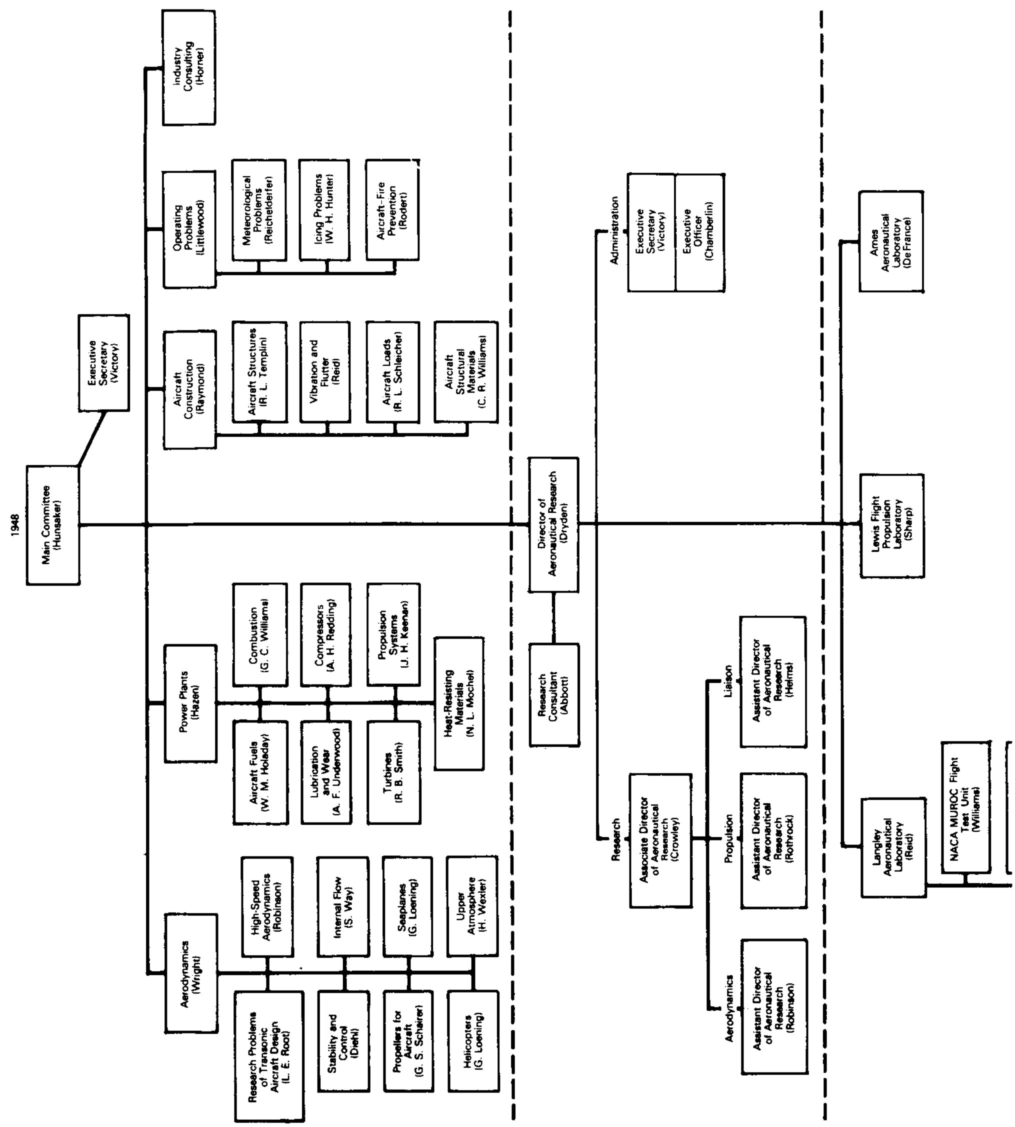
NACA Organization Chart, 1918 (hypothetical)

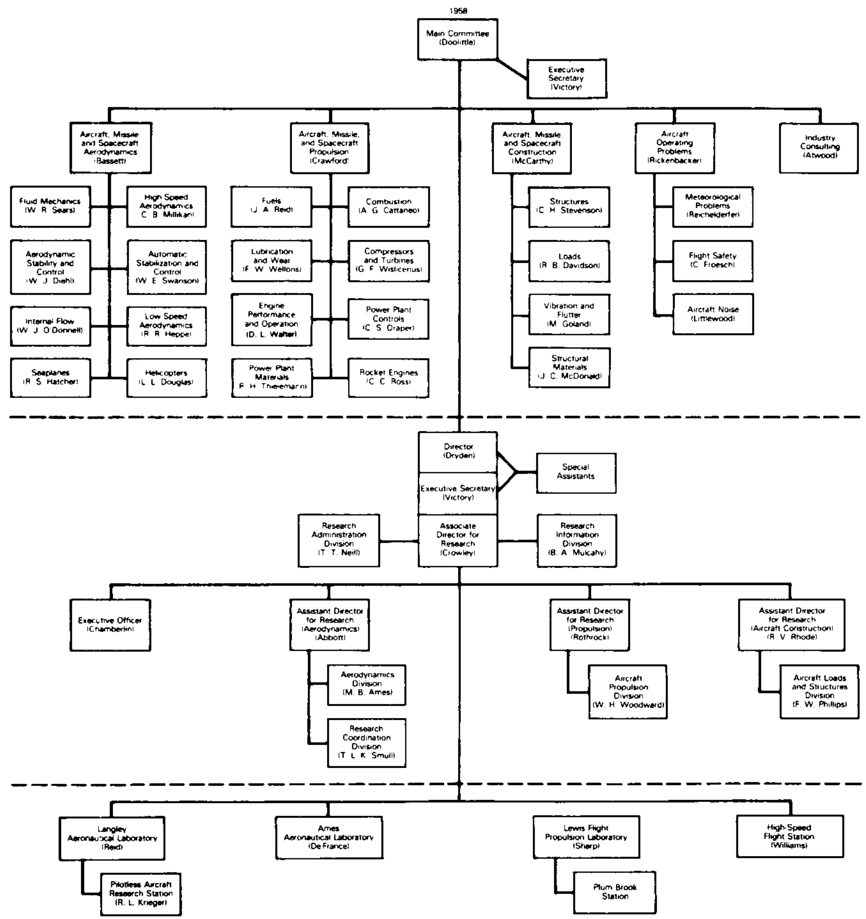


NACA Organization Chart, 1928 (hypothetical)



NACA Organization Chart, 1938 (hypothetical)


1948
Main Committee (Hunsaker)
Executive Secretary (Victory)
Industry Consulting (Horner)
Operating Problems (Littlewood)
Meteorological Problems (Reichelderfer)
Icing Problems (W. H. Hunter)
Aircraft-Fire Prevention (Rodert)
Aircraft Construction (Raymond)
Aircraft Structures (R. L. Templin)
Vibration and Flutter (Reid)
Aircraft Loads (R. L. Schleicher)
Aircraft Structural Materials (C. R. Williams)
Power Plants (Hazen)
Combustion (G. C. Williams)
Compressors (A. H. Redding)
Propulsion Systems (J. H. Keenan)
Heat-Resisting Materials (N. L. Mochel)
Aircraft Fuels (W. M. Holaday)
Lubrication and Wear (A. F. Underwood)
Turbines (R. B. Smith)
Aerodynamics (Wright)
High-Speed Aerodynamics (Robinson)
Internal Flow (S. Way)
Seaplanes (G. Loening)
Upper Atmosphere (H. Wexler)
Research Problems of Transonic Aircraft Design (L. E. Root)
Stability and Control (Diehl)
Propellers for Aircraft (G. S. Schairer)
Helicopters (G. Loening)
Director of Aeronautical Research (Dryden)
Research Consultant (Abbott)
Administration
Executive Secretary (Victory)
Executive Officer (Chamberlin)
Research
Associate Director of Aeronautical Research (Crowley)
Liaison
Assistant Director of Aeronautical Research (Helms)
Propulsion
Assistant Director of Aeronautical Research (Rothrock)
Aerodynamics
Assistant Director of Aeronautical Research (Robinson)
Ames Aeronautical Laboratory (De France)
Lewis Flight Propulsion Laboratory (Sharp)
Langley Aeronautical Laboratory (Reid)
NACA MUROC Flight Test Unit (Williams)



NACA Organization Chart, 1958 (hypothetical)

Table D–1
Manning Level

	HQ	Field	Total	Total Salaries	Average Salary
1915*	1	0	1	$1,200	$1,200
1916*	1	0	1	1,200	1,200
1917*	5	0	5	5,500	1,100
1918*	37	**3	40	62,220	1,556
1919	33	***11	44	86,650	1,969
1920	36	***27	63	125,380	1,990
1921	22	44	66	123,967	1,878
1922	13	56	69	****98,245	1,424
1923	8	75	83	****100,092	1,206
1924	23	77	100	204,436	2,044
1925	23	107	130	270,192	2,078
1926	24	121	145	302,648	2,087
1927	24	141	165	341,574	2,070
1928	29	156	185	387,372	2,094
1929	21	177	198	448,771	2,266
1930	38	202	240	532,265	2,218
1931	43	240	283	624,931	2,208
1932	44	268	312	675,176	2,164
1933	44	268	312	671,321	2,152
1934	41	266	307	668,640	2,178
1935	38	250	288	655,860	2,277
1936	50	343	393	861,719	2,193
1937	48	398	446	950,415	2,131
1938	50	430	480	1,042,510	2,172
1939	53	447	500	1,064,871	2,130
1940	64	598	662	1,418,385	2,143
1941	80	797	877	1,875,414	2,138
1942	132	1,642	1,774	3,492,210	1,969
1943	131	2,634	2,765	5,702,099	2,062
1944	124	4,370	4,494	9,748,786	2,169
1945	119	5,958	6,077	13,999,593	2,304
1946	117	5,336	5,453	15,549,016	2,851
1947	157	5,773	5,930	19,322,625	3,260
1948	125	6,138	6,263	21,438,303	3,423
1949	**141	6,915	7,056	25,068,351	3,553
1950	157	7,129	7,286	29,061,389	3,989
1951	172	7,533	7,705	32,682,192	4,242
1952	168	5,540	7,708	35,226,912	4,570
1953	168	7,487	7,655	36,365,275	4,751
1954	157	7,000	7,157	36,708,193	5,129
1955	155	7,415	7,570	39,505,216	5,219
1956	163	7,765	7,928	44,586,938	5,624
1957	258	7,889	8,147	49,250,032	6,117
1958	**276	7,765	8,041	51,376,373	6,389

*At end of calendar year ** Estimate *** LMAL figures **** Figures for these years, published in *The Budget of the United States*, are inexplicably out of line with those for previous and subsequent years.

Table D-2
Key NACA Positions, 1938-1958

Headquarters

DIRECTOR	
Director of Aeronautical Research	1938-1949
Director	1950-1958
George W. Lewis (1938-1947)	
Hugh L. Dryden (1948-1958)	
EXECUTIVE SECRETARY	
Secretary and Field Coordinator	1938-1945
Executive Secretary	1946-1958
John F. Victory (1938-1958)	
ASSISTANT TO THE DIRECTOR FOR RESEARCH MANAGEMENT	1951-1958
Clinton H. Dearborn (1951-1954)	
Clotaire Wood (1955-1958)	
ASSISTANT TO THE DIRECTOR	1952-1958
Robert E. Littell (1952-1958)	
ASSISTANT TO THE EXECUTIVE SECRETARY	
Information and Editorial Specialist	1951
Assistant to the Executive Secretary	1952-1958
Walter T. Bonney (1951-1958)	
LEGAL ADVISER	
Special Assistant to the Executive Secretary	1954-1957
Legal Adviser	1958
Paul G. Dembling (1954-1958)	
SECURITY OFFICER	1951-1958
Robert L. Bell (1951-1958)	
ASSOCIATE DIRECTOR FOR RESEARCH	
Associate Director of Aeronautical Research	1948-1949
Associate Director for Research	1950-1958
John W. Crowley, Jr. (1948-1958)	
CHIEF, RESEARCH ADMINISTRATION DIVISION	
Chief, Research Administration	1949
Assistant for Research Administration	1950-1951
Technical Assistant for Research Management	1952-1955
Chief, Research Administration Division	1956-1958
Thomas T. Neill (1949-1958)	
CHIEF, RESEARCH INFORMATION DIVISION	
Chief, Office of Aeronautical Intelligence	1942-1951
Chief, Research Information Division	1952-1958
Margaret M. Muller (1942-1949)	
Eugene B. Jackson (1950-1956)	
Bertram A. Mulcahy (1957-1958)	
ASSISTANT DIRECTOR FOR RESEARCH (AERODYNAMICS)	
Research Consultant	1948-1950
Assistant Director for Research	1950-1951
Assistant Director for Research (Aerodynamics)	1952-1958
Ira H. Abbott (1948-1958)	

CHIEF, AERODYNAMICS DIVISION	
Chief, Aerodynamics	1949
Chief, Aerodynamics Division	1950–1958
Milton B. Ames, Jr. (1949–1958)	
CHIEF, RESEARCH COORDINATION DIVISION	
Coordinator of Research	1940–1941
Chief of Coordination Division	1942–1943
Chief of Research Coordination	1944–1949
Chief, Research Coordination Division	1950–1958
S. Paul Johnston (1940–1941)	
Russell G. Robinson (1942–1947)	
(vacant, 1948)	
Thomas L. K. Smull (1949–1958)	
ASSISTANT DIRECTOR FOR RESEARCH (PROPULSION)	
Assistant Director of Aeronautical Research	1948–1949
Assistant Director for Research	1950–1951
Assistant Director for Research (Propulsion)	1952–1958
Addison M. Rothrock (1948–1958)	
CHIEF, AIRCRAFT PROPULSION DIVISION	
Chief, Propulsion and Aircraft Construction	1949
Chief, Aircraft Propulsion Division	1950–1958
Robert E. Littell (1949–1951)	
William H. Woodward (1952–1958)	
ASSISTANT DIRECTOR FOR RESEARCH (AIRCRAFT CONSTRUCTION)	
Assistant Director of Aeronautical Research	1948–1949
Assistant Director for Research	1950–1951
Assistant Director for Research (Aircraft Construction)	1952–1958
Russell G. Robinson (1948–1949)	
Richard V. Rhode (1950–1958)	
CHIEF, AIRCRAFT LOADS AND STRUCTURES DIVISION	1950–1958
Franklyn W. Phillips (1950–1958)	
EXECUTIVE OFFICER	
Assistant Secretary and Executive Officer	1937–1945
Executive Officer	1946–1958
Edward H. Chamberlin (1937–1958)	
BUDGET OFFICER	1948–1958
Ralph E. Ulmer (1948–1958)	
PERSONNEL OFFICER	
Chief, Personnel Division	1942–1945
Personnel Officer	1946–1958
Rosa D. Smith (1942–1945)	
Parmely C. Daniels (1946–1947)	
Robert J. Lacklen (1948–1958)	
PROCUREMENT AND SUPPLY OFFICER	
Chief, Purchase Division	1942–1947
Chief of Procurement and Contract	1948–1949
Chief of Procurement and Contract Division	1950–1952
Chief of Procurement and Supply Division	1953–1955
Procurement and Supply Officer	1956–1958
Virginia M. Kerlin (1942–1947)	
Ralph E. Cushman (1948–1958)	

FISCAL OFFICER

Chief, Finance Division	1942–1947
Chief of Finance	1948–1949
Fiscal Officer	1950–1958

Ruth Scott (1942–1949)
William M. Thompson (1950–1958)

ASSISTANT TO THE EXECUTIVE OFFICER, MANAGEMENT IMPROVEMENT DIVISION

Policies and Procedures Officer	1950–1951
Management Improvement Officer	1952–1956
Assistant to the Executive Officer, Management Improvement Division	1957–1958

William M. Shea (1950–1958)

SAFETY OFFICER 1953–1958
George D. McCauley (1953–1958)

Discontinued Positions

ASSISTANT DIRECTOR FOR RESEARCH

Chief of Military Liaison	1942–1943
Chief of Military Research	1944–1945
Assistant Director of Aeronautical Research	1946–1949
Assistant Director for Research	1950–1951

Charles H. Helms (1942–1951)

RESEARCH INFORMATION OFFICER

Chief of Division of Research Information	1946–1947
Chief of Research Information	1948–1949
Research Information Officer	1950–1951

E. Eugene Miller (1946–1951)

CHIEF, DRAFTING DIVISION 1942–1947
Henry E. Lorentz (1942–1943)
Edgar N. Hammerly (1944–1947)

CHIEF, DIVISION OF PUBLICATIONS AND SUPPLIES 1942–1947
Eugene M. Reading (1942–1943)
John A. Nance (1944)
Frank J. Clarke (1945–1947)

CHIEF, CORRESPONDENCE DIVISION 1942–1947
Catherine Wheeler (1942–1947)

CLASSIFICATION-ORGANIZATION OFFICER 1946–1947
Robert J. Lacklen (1946–1947)

CHIEF OF DIVISION OF TECHNICAL ASSISTANTS 1942
Robert E. Littell (1942)

TECHNICAL ASSISTANT IN EUROPE 1938–1940
John J. Ide (1938–1940)

Lewis Laboratory

DIRECTOR

Administrative Officer	1942
Manager	1943–1947
Director	1948–1958

Edward R. Sharp (1942–1958)

ASSOCIATE DIRECTOR

Chief of Research	1950–1952
Associate Director	1953–1958

Abe Silverstein (1950–1958)

ASSISTANT DIRECTOR	
Assistant Chief of Research	1950–1952
Assistant Director	1953–1958
Eugene J. Manganiello (1950–1958)	
TECHNICAL ASSISTANT TO ASSOCIATE DIRECTOR	1957–1958
Oscar W. Schey (1957–1958)	
ASSISTANT TO DIRECTOR (RESEARCH COORDINATION AND LIAISON)	
Assistant Chief of Research for Coordination and Liaison	1952
Assistant to Director (Research Coordination and Liaison)	1953–1958
John H. Collins, Jr. (1952–1958)	
BUDGET OFFICER	1948–1958
William J. McCann (1948–1951)	
Victor Gordon (1952–1958)	
CHIEF ADMINISTRATOR, TECHNICAL SERVICES, PLUM BROOK REACTOR FACILITY	
Chief, Administrative and Technical Operations, Plum Brook Reactor Facility	1956–1957
Chief Administrator, Technical Services, Plum Brook Reactor Facility	1958
James R. Braig (1956–1958)	
CHIEF, PROPULSION CHEMISTRY DIVISION	
Chief, Fuels and Combustion Research Division	1950–1956
Chief, Propulsion Chemistry Division	1957–1958
Walter T. Olsen (1950–1958)	
CHIEF, MATERIALS AND STRUCTURES DIVISION	
Chief, Thermodynamics Division	1943–1944
Chief, Thermodynamics Research Division	1945
Chief, Fuels and Thermodynamics Division	1946
Chief, Fuels and Thermodynamics Research Division	1947–1951
Chief, Materials and Thermodynamics Research Division	1952–1956
Chief, Materials and Structures Division	1957–1958
Benjamin Pinkel (1943–1956)	
Samuel S. Manson (1957–1958)	
CHIEF, PHYSICS DIVISION	1950–1958
Newell D. Sanders (1950–1958)	
CHIEF, PROPULSION AERODYNAMICS DIVISION	
Chief, Supersonic Propulsion Division	1950–1956
Chief, Propulsion Aerodynamics Division	1957–1958
John C. Evvard (1950–1958)	
ASSOCIATE CHIEF, PROPULSION AERODYNAMICS DIVISION	
Associate Chief, Supersonic Propulsion Division	1956
Associate Chief, Propulsion Aerodynamics Division	1957–1958
De Marquis D. Wyatt (1956–1958)	
CHIEF, PROPULSION SYSTEMS DIVISION	
Chief, Engine Research Division	1943–1945
Chief, Engine Performance and Materials Division	1946–1949
Chief, Engine Research Division	1950–1956
Chief, Propulsion Systems Division	1957–1958
John H. Collins, Jr. (1943–1949)	
Eugene W. Wasielewski (1950–1952)	
Bruce T. Lundin (1953–1958)	

ASSOCIATE CHIEF, PROPULSION SYSTEMS DIVISION
Associate Chief, Engine Research Division 1956
Associate Chief, Propulsion Systems Division 1957–1958
David S. Gabriel (1956–1958)
CHIEF, FLUID SYSTEMS DIVISION
Associate Chief, Physics Division 1953–1955
Chief, Flight Problems Research Division 1956
Chief, Fluid Systems Division 1957–1958
J. Irving Pinkel (1953–1958)
CHIEF, NUCLEAR REACTOR DIVISION 1957–1958
Leroy V. Humble (1957–1958)
CHIEF, RESEARCH SERVICES DIVISION 1958
J. H. Hall (1958)
CHIEF, RESEARCH REPORTS DIVISION 1950–1958
Victor Gordon (1950)
Bertram A. Mulcahy (1951–1956)
James J. Modarelli (1957–1958)
ADMINISTRATIVE MANAGEMENT OFFICER
Assistant to the Director 1948–1949
Administrative Management Officer 1950–1958
John D. Tousignant (1948–1952)
John S. Brown (1955–1958)
PERSONNEL OFFICER
Chief, Personnel Division 1946–1948
Personnel Officer 1949–1958
John D. Tousignant (1940–1947)
Robert W. Schmidt (1948)
John S. Brown (1949–1953)
Michael J. Vaccaro (1954–1958)
FISCAL OFFICER
Chief, Auditing Division 1945
Chief, Fiscal Division 1946–1949
Fiscal Officer 1950–1958
Carl H. Dawson (1945–1947)
John B. Clouser (1948–1950)
Edward J. Baxter (1951–1952)
Leslie F. Hinz (1953–1954, 1958)
Victor Gorden (1955–1957)
CHIEF, ADMINISTRATIVE SERVICES DIVISION 1953–1958
H. Burton Bracy (1953–1954)
Charles D. Ferraro (1955)
Robert W. Schmidt (1956–1958)
PROCUREMENT AND SUPPLY OFFICER
Chief, Procurement Division 1946–1949
Procurement Officer 1950–1952
Procurement and Supply Officer 1953–1958
James R. Braig (1946–1947)
William Dey, Jr. (1948–1955)
Eugene C. Braig, Jr. (1956–1958)
CHIEF, TECHNICAL SERVICES OFFICE
Chief Service Engineer 1948
Chief of Technical Services 1951–1952

Chief, Technical Services Office 1953–1958
Charles A. Herrmann (1948–1958)

CHIEF, ENGINEERING DIVISIONS OFFICE
Assistant Chief of Technical Services—Engineering 1952
Chief, Engineering Divisions Office 1953–1958
William J. McCann (1952–1958)

CHIEF, ELECTRICAL ENGINEERING DIVISION 1949–1958
Kenneth D. Brumbaugh (1949–1953)
Myron J. Pollyea (1954–1958)

CHIEF, MECHANICAL ENGINEERING DIVISION 1949–1958
Harry Kotlas (1949–1951)
Kevork K. Nahigyan (1952–1958)

CHIEF, MECHANICAL DIVISIONS OFFICE
Assistant Chief of Technical Services; Chief of Operations 1951
Assistant Chief of Technical Services—Operations 1952
Chief, Mechanical Divisions Office 1953–1958
Stewart V. Kramer (1951–1958)

ASSOCIATE CHIEF, MECHANICAL DIVISIONS OFFICE 1953–1958
Austin F. Reader (1953–1958)

CHIEF, PLANT SERVICES DIVISION
Chief, Plant Operations Division 1951–1952
Chief, Plant Services Division 1953–1958
John C. Everett (1951–1958)

CHIEF, MECHANICAL SERVICES DIVISION 1945–1958
William E. Dewey (1945–1950)
Austin F. Reader (1951–1952)
Bruno A. Pinnow (1955–1958)

CHIEF, FACILITIES OPERATIONS DIVISION 1953–1958
Austin F. Reader (1953–1954)
Jean N. Vivien (1955–1958)

CHIEF, FABRICATION DIVISION
Head, Service Section 1942
Chief, Technical Service Division 1943–1944
Chief, Fabrication Division 1945–1949
Dan White (1942–1950)
William E. Dewey (1951–1954)
Austin F. Reader (1955–1958)

CHIEF, CONSTRUCTION CONTRACT ADMINISTRATION DIVISION
Contract and Construction Administrator 1950–1952
Chief, Contract and Construction Administrator's Office 1953–1956
Chief, Construction Contract Administration Division 1957–1958
James R. Braig (1950–1955)
Charles A. Herrmann (1956)
N. Philip Miller (1957–1958)

CHIEF, FACILITIES ENGINEERING DIVISION
Chief, Buildings and Grounds Division 1945–1947
Chief, Civil Engineering Division 1948–1950
Chief, Facilities Engineering Division 1951–1958
Franklin J. Hobson (1945)
Beverly G. Gulick (1946–1958)

Discontinued Positions

CHIEF, ENGINEERING DRAFTING DIVISION
- Chief, Drafting Division 1949–1950
- Chief, Engineering Drafting Division 1951–1957

Lawrence T. Stitt (1949–1957)

CHIEF, RESEARCH OPERATIONS, PLUM BROOK REACTOR FACILITY 1956

Michael F. Valerino (1956)

CHIEF, CONTRACT ADMINISTRATION DIVISION 1951–1956

Mabry V. Organ (1951–1955)
N. Philip Miller (1956)

CHIEF, COMPRESSOR & TURBINE RESEARCH DIVISION
- Chief, Supercharger Division 1943–1944
- Chief, Supercharger and Airflow Research Division 1945
- Chief, Compressor and Turbine Division 1946
- Chief, Compressor & Turbine Research Division 1947–1956

Oscar W. Schey (1943–1956)

ASSISTANT DIRECTOR 1956

Eugene W. Wasielewski (1956)

ASSOCIATE CHIEF, TECHNICAL SERVICES OFFICE 1953–1955

Eugene W. Wasielewski (1953–1955)

ASSISTANT FISCAL OFFICER 1953–1954

Leslie F. Hinz (1953–1954)

ASSOCIATE CHIEF, FUELS AND COMBUSTION RESEARCH DIVISION 1953–1954

Louis C. Gibbons (1953–1954)

CHIEF, ELECTRICAL OPERATIONS DIVISION 1952

Walter Maxim (1952)

CHIEF, MECHANICAL OPERATIONS DIVISION
- Chief, Machinery Operating Division 1949–1950
- Chief, Mechanical Operations Division 1951–1952

Thomas M. McComb (1949–1952)

PROCEDURES AND METHODS OFFICE
- Administrative Assistant 1942
- Chief, Administrative Division 1943–1944
- Administrative Officer 1945
- Chief, Administrative Department 1946–1947
- Administrative Officer 1948–1949
- Procedures and Methods Officer 1950

Helen G. Ford (1942)
(Vacant, 1943)
Eugene C. Braig, Jr. (1944–1950)

EXECUTIVE OFFICER 1948–1950

Robert C. Sessions (1948–1950)

ASSISTANT CHIEF SERVICE ENGINEER
- Chief, Engine Components Research Division 1947
- Chief, Engineering Services Division 1946–1947
- Assistant Chief Service Engineer 1948–1950

Charles S. Moore (1943–1948)
(vacant, 1949)
William J. McCann (1950)

CHIEF, ENGINEERING DIVISIONS 1950

Charles S. Moore (1950)

TECHNICAL ASSISTANT TO THE DIRECTOR	
Executive Engineer	1943–1947
Technical Assistant to the Director	1948–1949
Carlton Kemper (1943–1949)	
TECHNICAL ASSISTANT TO THE DIRECTOR	1948–1949
Robert F. Selden (1948–1949)	
TECHNICAL ASSISTANT TO THE DIRECTOR	1948–1949
Jesse H. Hall (1948–1949)	
CHIEF, INSTRUMENT DIVISION	1945–1949
Robert E. Tozier (1945–1949)	
CHIEF, WIND TUNNEL AND FLIGHT DIVISION	
Chief, Flight Research Division	1943–1945
Chief, Wind Tunnel and Flight Division	1946–1949
Joseph R. Vensel (1943–1945)	
Abe Silverstein (1946–1949)	
CHIEF, ENGINEERING SERVICES DIVISION	
Head, Inspection Section	1942
Chief, Engineering Services Divison	1943–1944
Service Branch Engineer	1945
Chief, Service Department	1946–1947
Chief, Engineering Services Division	1948
Charles A. Herrmann (1942–1947)	
Kenneth D. Brumbaugh (1948)	
CHIEF, ADMINISTRATIVE SERVICES DIVISION	1946–1947
Robert W. Schmidt (1946–1947)	
CHIEF OF RESEARCH	
Chief, Research Department	1946
Chief of Research	1947
Addison M. Rothrock (1946–1947)	
CHIEF, FUELS AND LUBRICANTS RESEARCH DIVISION	
Chief, Fuels and Lubricants Division	1943–1944
Chief, Fuels and Lubricants Research Division	1945
Addison M. Rothrock (1943–1945)	
CHIEF, ICING RESEARCH DIVISION	1945
Wilson H. Hunter (1945)	
CHIEF, DESIGN DIVISION	
Chief, Construction Division	1942–1944
Chief, Design Division	1945
Ernest G. Whitney (1942)	
Beverly G. Gulick (1943–1945)	
CHIEF, ENGINE INSTALLATION DIVISION	1943–1945
Ernest G. Whitney (1943–1944)	
Abe Silverstein (1945)	
CHIEF, TRAINING DIVISION	
Head, Apprentice Administration	1942–1943
Chief, Training Division	1944–1945
Charles A. Hulcher (1942–1945)	
CHIEF, OFFICE SERVICES DIVISION	
Chief Clerk	1942–1943
Chief, Office Services Division	1944–1945
George C. Lumpkin (1942–1945)	
CHIEF, AUDITING DIVISION	1942
Thomas A. Pace (1942)	

HEAD, ARCHITECTURAL DESIGN AND DRAFTING SECTION 1942
Harrison A. Underwood (1942)
HEAD, SPECIFICATIONS SECTION 1942
Howard O. Fry (1942)

Langley Laboratory

DIRECTOR
Engineer-in-Charge 1938–1947
Director 1948–1958
Henry J. E. Reid (1938–1958)
ASSOCIATE DIRECTOR
Chief, Research Department 1944–1947
Chief of Research 1948–1952
Associate Director 1953–1958
John W. Crowley, Jr. (1944–1947)
Floyd L. Thompson (1948–1958)
EXECUTIVE ASSISTANT AND BUDGET OFFICER
Executive Assistant 1948–1950
Executive Assistant and Budget Officer 1951–1958
Rufus O. House (1948–1958)
CHIEF, RESEARCH REPORTS DIVISION 1957–1958
Henry A. Fedziuk (1957–1958)
ASSISTANT DIRECTOR
Assistant Chief, Research Department 1947
Assistant Chief of Research 1948–1952
Assistant Director 1953–1958
Floyd L. Thompson (1947)
John Stack (1948–1958)
CHIEF, COMPRESSIBILITY RESEARCH DIVISION 1944–1958
John Stack (1944–1947)
John V. Becker (1948–1958)
CHIEF, FULL-SCALE RESEARCH DIVISION 1944–1958
Clinton H. Dearborn (1944–1950)
Eugene C. Draley (1951–1958)
CHIEF, THEORETICAL MECHANICS DIVISION
Chief, Physical Research Division 1938–1950
Chief, Theoretical Aerodynamics Division 1951–1955
Chief, Theoretical Mechanics Division 1956–1958
Theodore Theodorsen (1938–1946)
Carl Kaplan (1947–1955)
Clinton E. Brown (1956–1958)
CHIEF, UNITARY PLAN WIND TUNNEL DIVISION 1955–1958
Herbert A. Wilson, Jr. (1955–1958)
ASSISTANT DIRECTOR
Assistant Chief of Research 1952
Assistant Director 1953–1958
Robert L. Gilruth (1952–1958)
CHIEF, DYNAMIC LOADS DIVISION
Head, Aerodynamic and Hydrodynamic Loads Research 1942–1943
Chief, Aircraft Loads Division 1944–1949
Chief, Dynamic Loads Division 1950–1958
Richard V. Rhode (1942–1949)
Isadore E. Garrick (1950–1958)

CHIEF, PILOTLESS AIRCRAFT RESEARCH DIVISION
Chief, Auxiliary Flight Research Division........ 1946
Chief, Pilotless Aircraft Research Division........ 1947–1958
Robert R. Gilruth (1946–1951)
Joseph A. Shortal (1952–1958)
CHIEF, STRUCTURES RESEARCH DIVISION
Head, Structures Research Laboratory........ 1942–1943
Chief, Structures Research Division........ 1944–1958
Eugene E. Lundquist (1942–1951)
John E. Duberg (1952–1956)
Richard R. Heldenfels (1957–1958)
ASSISTANT DIRECTOR OF RESEARCH
Assistant Chief, Research Department........ 1947
Assistant Chief of Research........ 1948–1952
Assistant Director of Research........ 1953–1958
Ira H. Abbott (1947)
Hartley A. Soulé (1948–1958)
CHIEF, FLIGHT RESEARCH DIVISION
Chief Test Pilot........ 1938–1943
Chief, Flight Research Division........ 1944–1958
William H. McAvoy (1938–1940)
Melvin N. Gough (1941–1958)
CHIEF, HYDRODYNAMICS DIVISION........ 1938–1958
Starr Truscott (1938–1946)
John B. Parkinson (1947–1958)
CHIEF, STABILITY RESEARCH DIVISION
Head, Stability Research........ 1942–1943
Chief, Stability Research Division........ 1944–1958
Hartley A. Soulé (1942–1947)
Thomas A. Harris (1948–1958)
CHIEF, INSTRUMENT RESEARCH DIVISION
Head, Instrument Research........ 1942–1943
Chief, Instrument Research Division........ 1944–1958
Edmond C. Buckley (1942–1947, 1949–1958)
Morton J. Stoller (1948)
CHIEF OF TECHNICAL SERVICES
Chief, Technical Service Division........ 1938–1943
Chief, Technical Service Department........ 1944–1946
Chief, Administrative & Technical Service Department........ 1947
Chief of Administrative & Technical Services........ 1948–1954
Chief of Technical Services........ 1955
Ernest Johnson (1938–1953)
(Vacant, 1954)
Percy J. Crain (1955–1958)
CHIEF, ENGINEERING SERVICE DIVISION........ 1944–1958
John C. Messick (1944–1958)
CHIEF, MECHANICAL SERVICE DIVISION........ 1944–1958
Percy J. Crain, Jr. (1944–1954)
William B. Mayo (1955–1958)
CHIEF, MAINTENANCE DIVISION
Head, Maintenance Section........ 1942–1943
Chief, Maintenance Division........ 1944–1951, 1953–1958
Walter H. Reiser (1942–1951)
Mervin Forrest(1953–1958)

CHIEF, ELECTRICAL SERVICE DIVISION	1955–1958
Joseph Getsug (1955–1958)	
CHIEF, ADMINISTRATIVE SERVICES	
Administrative Officer	1938–1943
Chief, Administrative Department	1944
Administrative Officer	1945–1947
Assistant Chief of Administrative & Technical Services	1948–1949
Administrative Management Office	1950–1952
Administrative Management Office & Assistant Chief, Administrative & Technical Services	1953–1954
Chief, Administrative Services	1955–1958
Edward R. Sharp (1938–1940)	
W. Kemble Johnson (1940–1943, 1945)	
Elton W. Miller (1944, 1946–1958)	
FISCAL OFFICER	
Chief, Fiscal Division	1944–1950
Assistant Administrative Management Officer	1951
Fiscal Officer	1952–1958
H. Arthur Samet (1944–1951)	
Edward A. Howe (1952–1958)	
CHIEF, OFFICE SERVICES DIVISION	
Chief, General Services Division	1948–1956
Chief, Office Services Division	1957–1958
Robert E. Mixon (1946–1956)	
Edward T. Maher (1957–1958)	
ASSISTANT CHIEF, ADMINISTRATIVE SERVICES AND PERSONNEL OFFICER	
Chief, Personnel Division	1944–1949
Personnel Officer	1940–1954
Assistant Chief, Administrative Services & Personnel Officer	1955–1958
T. Melvin Butter (1944–1945, 1948–1958)	
Dolphus E. Henry (1946–1947)	
CHIEF, PHOTOGRAPHIC DIVISION	1957–1958
Harry H. Hamilton (1957–1958)	
PROCUREMENT & SUPPLY OFFICE	
Chief, Procurement Division	1944–1949
Procurement Officer	1950–1952
Procurement & Supply Office	1953–1958
Sherwood L. Butler (1944–1958)	

Discontinued Positions

ASSISTANT CHIEF OF ADMINISTRATIVE & TECHNICAL SERVICES	1948–1954
Howard H. Morris (1948–1954)	
ACTING CHIEF, MUROC SPECIAL FLIGHT RESEARCH DIRECTOR	1948
Walter C. Williams (1948)	
CHIEF, CONSTRUCTION AND DESIGN DIVISION	
Construction Administrator	1941
Chief, Construction and Design Division	1942–1943
Edward R. Sharp (1941)	
Roy W. Hooker (1942–1943)	
HEAD, ELECTRIC POWER SECTION	1942
Gilbert T. Strailman (1942)	

HEAD, STOCK SECTION	1942
John A. Beigborn (1942)	
HEAD, INSTRUMENT CALIBRATION LABORATORY	1942
Robert E. Mixon (1942)	
HEAD, INSTRUMENT SERVICE	1942
James W. Elder (1942)	
HEAD, PRECISION MACHINE SHOP	1942
Ernest J. Shave (1942)	
HEAD, STRUCTURES LABORATORY SHOP	1942
Charles W. Wolf (1942)	
HEAD, FABRICATION, ERECTION, AND ASSEMBLY SHOP	1942
George M. Hearn (1942)	
HEAD, MODEL SHOP	1942
Percy R. Keffer (1942)	
HEAD, WEST MODEL SHOP	1942
William J. Lawton (1942)	
HEAD, DYNAMIC MODEL SHOP	1942
Francis S. Wolak (1942)	
HEAD, DRAFTING SECTION	1942
John C. Messick (1942)	
HEAD, PHOTOGRAPHIC LABORATORY	1942
Stanley B. Clason (1942)	
CHIEF, AERODYNAMICS DIVISION	1937–1943
Elton W. Miller (1937–1943)	
HEAD, COMPUTING SECTION	1942
Virginia Tucker (1942)	
HEAD, EDITORIAL OFFICE	1942
Pearl I. Young (1942)	
HEAD, HIGH-LIFT AND LATERAL-CONTROL RESEARCH	1942
Thomas A. Harris (1942)	
HEAD, AIR-FLOW RESEARCH	1942
Eastman N. Jacobs (1942)	
HEAD, FULL-SCALE TUNNEL	1942
Abe Silverstein (1942)	
HEAD, SIXTEEN-FOOT HIGH-SPEED TUNNEL	1942
David Biermann (1942)	
HEAD, EIGHT-FOOT HIGH-SPEED TUNNEL	1942
John Stack (1942)	
HEAD, NINETEEN-FOOT PRESSURE TUNNEL	1942
Carl J. Wenzinger (1942)	
HEAD, POWER PLANT INSTALLATION	1942
Clinton H. Dearborn (1942)	
HEAD, FLIGHT RESEARCH MANEUVERS	1942
Floyd L. Thompson (1942)	
CHIEF, AIRCRAFT ENGINEERING DIVISION	1938–1942
Carlton Kemper (1938–1942)	
HEAD, SUPERCHARGING AND COOLING RESEARCH	1942
Oscar W. Shey (1942)	
HEAD, FUELS AND LUBRICANTS RESEARCH	1942
Addison M. Rothrock (1942)	
HEAD, THERMODYNAMICS RESEARCH	1942
Benjamin Pinkel (1942)	

HEAD, AIRCRAFT ENGINE RESEARCH 1942
John H. Collins, Jr. (1942)
HEAD, OPERATIONS AND EXPERIMENTAL SET-UP 1942
John H. Hanks (1942)

Ames Laboratory

DIRECTOR
Engineer-in-charge 1941–1947
Director 1948–1958
Smith J. DeFrance (1941–1958)
ASSOCIATE DIRECTOR
Chief, Unitary Supersonic Wind Tunnel Plan 1950–1952
Associate Director 1953–1958
John F. Parsons (1950–1958)
ASSISTANT DIRECTOR
Assistant to the Director 1948–1949
Assistant Director 1950–1958
John F. Parsons (1948–1949)
Russell G. Robinson (1950–1958)
EXECUTIVE ASSISTANT AND BUDGET OFFICER
Budget Officer 1948–1949
Executive Assistant and Budget Officer 1950–1958
Ferril R. Mikle (1948–1958)
SUPERVISORY ARE, UNITARY WIND TUNNEL DIVISION
Chief, Unitary Wind Tunnel Plan Division 1955–1956
Supervisory ARE,* Unitary Wind Tunnel Division 1957–1958
Ralph S. Huntsberger, Jr. (1955–1958)
CHIEF, THEORETICAL AND APPLIED RESEARCH DIVISION
Chief, Aerodynamics Division 1941–1942
Chief, Theoretical and Applied Research Division 1943–1958
Donald H. Wood (1941–1958)
CHIEF, FULL-SCALE AND FLIGHT RESEARCH DIVISION
Chief, Construction Division 1942
Chief, Full-Scale and Flight Research Division 1943
John F. Parsons (1942–1949)
Harry J. Goett (1950–1958)
CHIEF, HIGH SPEED RESEARCH DIVISION 1946–1958
Harvey J. Allen (1946–1958)
ADMINISTRATIVE MANAGEMENT OFFICER
Administrative Officer 1941–1947, 1949
Chief, Administrative Division 1948
Administrative Management Officer 1950–1958
Arthur B. Freeman (1941–1958)
PERSONNEL OFFICER 1949–1958
M. Helen Davies (1949–1958)
PROCUREMENT & SUPPLY OFFICER
Procurement Officer 1951–1953
Procurement & Supply Officer 1954–1958
Alvin S. Hertzog (1951–1958)
FISCAL OFFICER 1951–1958
William V. Shaw (1951–1958)

*Aeronautical research engineer

CHIEF, ADMINISTRATIVE SERVICES BRANCH 1955–1958
Lucille D. Baker (1955–1958)
SUPERVISORY ARE, INSTRUMENT RESEARCH DIVISION
Chief, Service Division 1943–1951
Chief, Research Instrumentation and Engineering Services Division 1952–1955
Chief, Instrument Research Division 1956
Supervisory ARE, Instrument Research Division 1957–1958
(vacant, 1943)
James A. White (1944–1958)
CHIEF, ENGINEERING SERVICES DIVISION 1956–1958
Andre G. Buck (1956–1958)
CHIEF, TECHNICAL SERVICE DIVISION
Chief, Shop Division 1941–1951
Chief, Technical Service Division 1952–1958
Edward W. Betts (1941–1958)

Discontinued Positions

HEAD, MACHINE SHOP SECTION 1942
Harry G. Downs (1942)
HEAD, WIND TUNNEL MECHANICS SECTION 1942
John P. Houston (1942)
HEAD, MODEL SHOP SECTION 1942
William Ward (1942)
HEAD, ERECTION SHOP 1942
George E. Beelifant (1942)
HEAD, MAINTENANCE SECTION 1942
Alfred E. Wilson (1942)
HEAD, DRAFTING SECTION 1942
Edward H. A. Schnitker (1942)
HEAD, FLIGHT RESEARCH 1942
Lewis A. Rodert (1942)
CHIEF TEST PILOT 1941
William H. McAvoy (1941)
HEAD, SIXTEEN-FOOT WIND TUNNEL 1942
Manley J. Hood (1942)
HEAD, SEVEN-BY-TEN-FOOT WIND TUNNEL 1942
Harry J. Goett (1942)
HEAD, THEORETICAL AERODYNAMICS 1942
Harvey J. Allen (1942)
HEAD, INSTRUMENT LABORATORY 1942
Howard W. Kirshbaum (1942)
HEAD, INSTRUMENT SECTION 1942
James V. Kelley (1942)
HEAD, ELECTRICAL SECTION 1942
James A. White (1942)
ASSISTANT DIRECTOR
Assistant to the Director 1948–1949
Assistant Director 1950–1955
Carlton Bioletti (1948–1955)
ADMINISTRATIVE MANAGEMENT OFFICER
Assistant Administrative Management Officer 1952–1955
Administrative Management Office 1956–1957
Mamie G. Poole (1952–1957)

High-Speed Flight Station

CHIEF, NACA HIGH-SPEED FLIGHT STATION 1952–1958
Walter C. Williams (1952–1958)
HEAD, EDITORIAL AND LIBRARY SERVICE
Aeronautical Research Technical Assistant 1956–1957
Head, Editorial and Library Service 1957–1958
Helen N. Foley (1956–1958)
BUDGET OFFICER 1958
Martin A. Byrnes, Jr. (1958)
CHIEF, RESEARCH DIVISION 1955–1958
De E. Beeler (1955–1958)
HEAD, PROJECT COORDINATORS GROUP 1957–1958
Milton O. Thompson (1957–1958)
HEAD, DATA REDUCTION SECTION
ARS*, Aerodynamics Data Reduction and Analysis Branch 1956
Head, Data Reduction Section 1957–1958
Edward N. Videan (1956–1958)
HEAD, STABILITY AND CONTROL BRANCH
Head, Dynamic Stability and Analysis Branch 1957
Head, Stability and Control Branch 1958
Joseph Weil (1957–1958)
HEAD, AEROSTRUCTURES BRANCH
Head, Aerodynamics Load Branch 1956
Head, Aerostructures Branch 1957–1958
De E. Beeler (1956)
Frank S. Malvestuts, Jr. (1957)
Thomas F. Baker (1958)
HEAD, PERFORMANCE BRANCH
ARS, Aerodynamics Performance Branch 1956
Head, Performance Branch 1957–1958
Donald R. Bellman (1956–1958)
CHIEF, FLIGHT OPERATIONS DIVISION 1955–1958
Joseph R. Vensel (1955–1958)
HEAD, FLIGHT BRANCH 1956–1958
Aeronautical Research Pilot, Flight Branch 1956
Head, Flight Branch 1957–1958
Joseph A. Walker (1956–1958)
SUPERINTENDENT, AIRCRAFT MAINTENANCE BRANCH 1956–1958
Clyde G. Bailey (1956–1958)
ASSISTANT SUPERINTENDENT, MAINTENANCE BRANCH 1956–1958
Charles M. Hamilton (1956–1958)
ASSISTANT SUPERINTENDENT, AIRCRAFT MAINTENANCE BRANCH 1957–1958
Ralph H. Sparks (1957–1958)
CHIEF, INSTRUMENTATION DIVISION 1955–1958
Gerald M. Truszynski (1955–1958)
HEAD, INSTRUMENT DEVELOPMENT BRANCH
ARS, Electrical Instruments Development Branch 1956
Head, Instrument Development Branch 1957–1958
Kenneth C. Sanderson (1956–1958)

*Aeronautical research scientist

ASSISTANT SUPERINTENDENT, INSTRUMENT SHOP, INSTRUMENT OPERATIONS BRANCH 1956–1958
O. Norman Hayes, Jr. (1956–1958)

SUPERVISING INSTRUMENT CALIBRATION AND SERVICE ENGINEER 1956–1958
L. Russell Mills (1956–1958)

CHIEF, ADMINISTRATIVE DIVISION 1955–1958
Marion I. Kent (1955–1958)

PERSONNEL OFFICER 1956–1958
Phillip E. Walker (1956–1958)

FISCAL OFFICER 1956–1958
J. Leslie Garbett (1956–1957)
Arthur J. Lynch (1958)

PROCUREMENT AND SUPPLY OFFICER 1956–1958
Martin A. Byrnes, Jr. (1956–1957)
Morris E. Bowling (1958)

HEAD, BUILDING SERVICE BRANCH 1957–1958
Mechanical Engineer 1956
Head, Building Service Branch 1957–1958
Harold L. Richards (1956–1958)

Discontinued Positions

HEAD, FLUTTER AND VIBRATION SECTION 1957
Thomas F. Baker (1957)

HEAD, EXPERIMENTAL STABILITY AND CONTROL BRANCH
ARS, Stability & Control Branch 1956
Head, Experimental Stability & Control Branch 1957
Herbert M. Drake (1956)
Jack Fischel (1957)

Appendix E
Facilities

The NACA used and was used by its facilities. For many years the NACA had the best aeronautical research facilities in the world, and in many ways these facilities determined what the NACA would choose to do and be required to do. Having the world's only full-scale wind tunnel enabled the Committee to perform unique experiments, but it also dictated that the research program make full use of the full-scale tunnel. The same was true of the NACA's other research facilities, so that the agency waged an unending campaign to coordinate the needs of aeronautical research with full exploitation of the equipment on hand, retirement of old equipment, and development of new.

Headquarters

Headquarters was always a paper mill. It never conducted original research, nor did it maintain any research facilities other than its technical library. Editing, publishing, and distributing reports was as close as headquarters came to actually doing research; even here, the Langley laboratory performed many of the paperwork functions such as printing, photography, and artwork. The NACA headquarters thus consisted merely of its offices and library, located at the following sites in Washington, D.C.:

1915	State, War, and Navy Building, Constitution Avenue, N.W.
1916–1918	Munsey Building, 1329 E Street, N.W.
1918–1920	Bureau of Aircraft Production, Building D, 4th Street and Missouri Avenue, N.W.
1920–1941	Main Navy Building, Constitution Avenue
1941–1947	Leiter Mansion, Dupont Circle, 1500 New Hampshire Avenue, N.W.
1947–1954	1724 F Street, N.W.
1954–1958	Wilkens Building, 1512 H Street, N.W.
1958	Dolley Madison Building, 1520 H Street, N.W., acquired for NASA expansion

Laboratories

The NACA's research was conducted at its laboratories and their subsidiary stations. In order of their establishment and with their various titles, these were:

- Langley Aeronautical Laboratory 1920–1958
  - Langley Memorial Aeronautical Laboratory (1920–1948)
- Ames Aeronautical Laboratory 1940–1958
- Lewis Flight Propulsion Laboratory 1942–1958
  - Aircraft Engine Research Laboratory (1942–1947)
  - Flight Propulsion Research Laboratory (1947–1948)
- Pilotless Aircraft Research Station 1945–1958
  - Auxiliary Flight Research Station (1945–1946)

High Speed Flight Station 1946–1958
NACA Muroc Flight Test Unit (1946–1949)
High Speed Flight Research Station (1949–1954)
Plum Brook Station 1956–1958

WIND TUNNELS

A fundamental law of fluid dynamics is that a body immersed in a moving fluid experiences the same forces as if the body were moving and the fluid stationary, given that the relative speed of the fluid and the solid object is the same in both cases. This means that the conditions surrounding an airplane in flight can be replicated by holding the plane stationary and moving the air past it at a velocity comparable to flight speeds. Thus, wind tunnels.

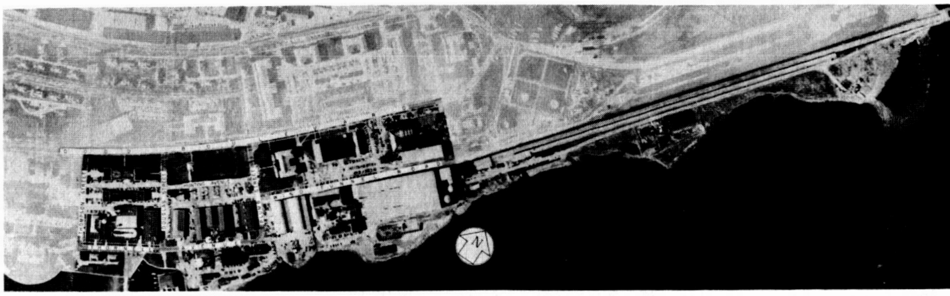
Advantages of wind tunnels over flight testing are economy, safety, and research versatility. A model airplane can be tested in a wind tunnel at a fraction of the cost of building and operating a full-scale prototype, and the airworthiness of new and experimental designs can be tested without risking a pilot's life. Wind-tunnel testing can simulate flight under conditions more controlled and measurable than would be possible in flight test. Even before man first flew, the wind tunnel was the principal tool of the aeronautical engineer.

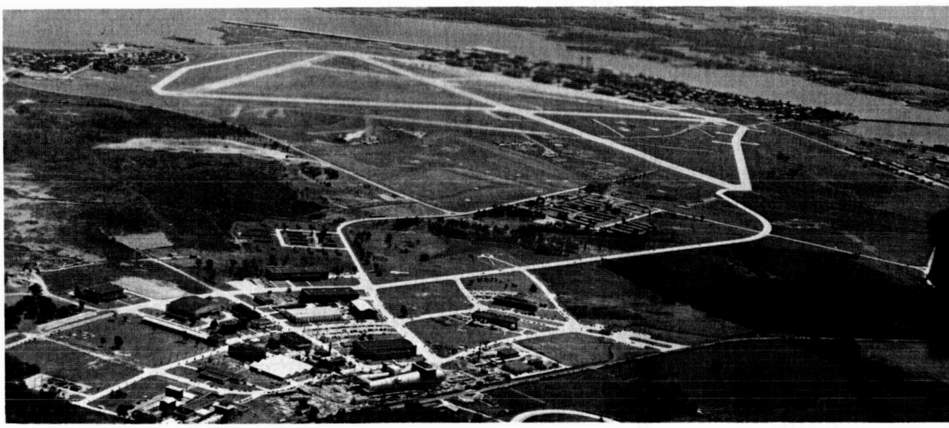
All wind tunnels have common features that circumscribe their characteristics and capabilities. All have a test section in which an airplane model or component—or even a complete airplane—can be fixed or suspended. The cross section may be round, oval, rectangular, or polygonal. Test sections may vary in size from a few inches up to the 40- by 80-foot dimensions of the Ames full-scale tunnel, still the largest in the world.* The test section may be open, closed, or ventilated.

Wind tunnels may be either return or nonreturn. Nonreturn tunnels draw air from the atmosphere, pass it through a tube that includes a test section, and discharge it into the atmosphere. Such tunnels are simple and inexpensive to build, but are inefficient and limited in the types of flow they can generate. Most sophisticated tunnels use a return-type circuit in one of three basic variations. The single-return tunnel passes the same air around a closed loop. Many such tunnels are designed so that the laboratory building encompasses the test section, with the rest of the tunnel winding a circuitous path outside like an overgrown appendage. The double-return tunnel is shaped like a squared figure-eight with the corners rounded and the test section located at the juncture of the two loops. Annular-return tunnels are doughnut-shaped in cross section. Longitudinally, they look like a tube within a capsule; air pushed around the inner shell of the capsule is channeled down the tube in the center, which contains the test section. Annular-return tunnels are generally small and entirely contained within their research building.

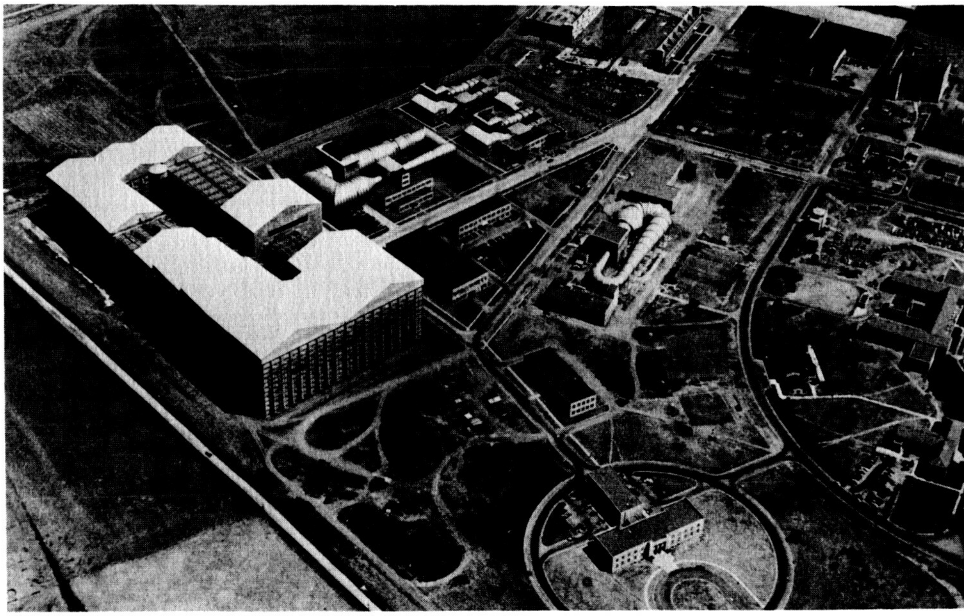
A major advantage of closed tunnels is that they can be pressurized, a technique that remains one of the NACA's greatest contributions to wind-tunnel technology. Comparability between conditions of wind-tunnel tests on models and conditions experienced by full-scale aircraft in flight depends on a dimensionless mathematical quantity known as Reynolds number (named for the 19th-century British engineer Osborne Reynolds). The Reynolds number is a flow-similarity parameter that describes forces acting on a body in motion with respect to the fluid in which it is immersed. The number is directly proportional to the size of the body and the density and relative

*At the time of this writing, the tunnel was being modified to provide an 80- by 120-foot test section.





Top, this highlighted view of Langley laboratory's east area taken from directly overhead in 1957 shows the NACA towing tanks (lower right) and the base runway. (Not all the highlighted facilities were the NACA's.) Middle, this aerial view of the Langley laboratory's west area shows the air force base and the east area in the background. Most clearly visible of the east-area facilities are the full-scale wind tunnel shown at the center top and the NACA tanks, extending to the left from the full-scale tunnel into the river. Bottom, a closeup aerial view of the Langley west area taken in 1949; the east area is out of the picture, to the upper right. (LaRC)



Ames Aeronautical Laboratory as it appeared at the end of World War II, dominated (as it still is) by the full-scale wind tunnel at left center. (ARC)

speed of the fluid, and inversely proportional to the viscosity of the fluid. Other things being equal, a model "moving" with respect to an airstream would have a smaller Reynolds number than a full-scale plane in flight. The easiest way to equalize the Reynolds numbers—and thus to obtain comparable flow conditions for the plane and the model—is to increase the speed *or density* of the airstream in which the model is immersed. To increase airspeed within a wind tunnel is a complicated and expensive undertaking that would violate equality of the ratio of airspeed to speed of sound, another condition for strict comparability. In a return-type tunnel, however, it is comparatively easy to increase air density by increasing air pressure. The NACA's first pressurized tunnel—Max Munk's variable-density tunnel of 1923—could pressurize the air to 20 atmospheres, making tunnel results on a 1/20th-scale model comparable to those of a full-size plane in the atmosphere.

The speed of a wind tunnel is the velocity of the airflow measured at the test section. Tunnels are customarily classified in the following speed ranges:

Class	Mach no. **	Mph at sea level
Low-speed	0 to 0.5	0 to 380
High-speed	0.5 to 0.9	380 to 684
Transonic	0.7 to 1.4	532 to 1,064
Supersonic	1.4 to 5.0	1,064 to 3,800
Hypersonic	5.0 to 10.0	3,800 to 7,600
Hypervelocity	10.0 and above	7,600 and up

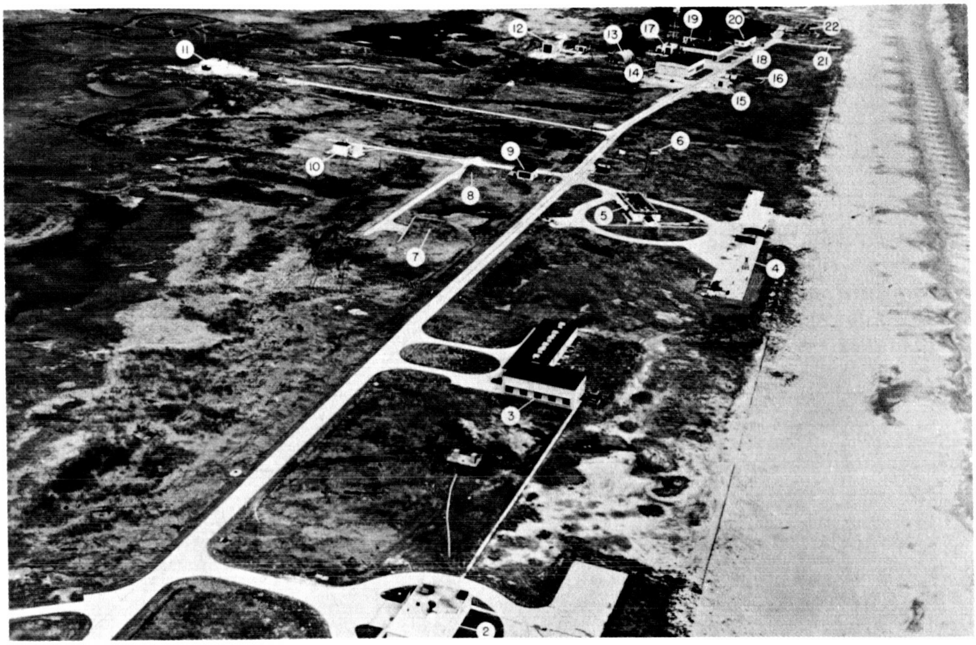
**Mach no. equals stream velocity/velocity of sound.

Aerial view of Lewis Flight Propulsion Laboratory as it appeared in 1955. An edge of the Cleveland municipal airport is visible at left center. (LeRC)

As aircraft speeds increased, wind-tunnel speeds had to increase. Above 300 to 400 mph, the compressibility of air begins to affect the results of scale-model tests. Thereafter, not only the Reynolds number but also the actual mach number must be matched between the model and the aircraft. A plane moving through the air at low speed sets up something like a bow wave, a layer of compressed air at the leading edges that moves ahead of the plane at the speed of sound, pushing the approaching air out of the way. When the plane moves near or above the speed of sound, the air has no time to get out of the way, and its collision with the plane produces shock waves—patterns of energy dispersion—with unique aerodynamic effects. High-speed wind tunnels are expensive to build and operate (the power required increases as the cube of the speed) and present major problems in turbulence, heating, and flow condensation, but they are indispensable to accurate testing in high-speed regimes of flight. Some of the NACA's greatest achievements were the development and application of high-speed tunnels, especially in the anomalous transonic region.

In most conventional wind tunnels the air is moved by fans powered by electric motors. Some tunnels, however, produce the airstream differently: Blowdown tunnels use a jet of air from a pressurized reservoir. Induction tunnels use a stream of air flowing into a vacuum chamber. Hypervelocity tunnels may combine these methods, passing air from a pressurized vessel across the test section and into an evacuated vessel at pressure ratios of several hundred. Although blowdown and induction-drive systems can produce extremely high-velocity air, they are severely limited by the brief availability of that air and their limited ability to modulate the velocity. At the extreme end of the spectrum is the counterflow tunnel in which a model is shot from a gun into a high-velocity airstream from a blowdown or induction-drive system. Some wind tunnels in the NACA laboratories shared drive systems, and some blowdown tunnels used compressed air stored in nearby pressure tunnels.

These basic characteristics, common to most wind tunnels, by no means encompass all the features, capabilities, and equipment involved in wind-tunnel research. Almost all wind tunnels employ a complex array of balances and other measuring devices designed specifically for the purpose. Most closed-circuit tunnels use tunnel vanes to guide the airflow smoothly around the corners in the circuit. Most tunnels use complex arrays of settling chambers, screens, and throat contractions to smooth and straighten the airstream as it accelerates into the test section. A variety of model-support systems is used, depending on the configuration of the test object. Some tunnels use smoke to help visualize air flow. Some are rigged for Schlieren photography, a special technique that records shock waves produced at high speeds. Some tunnels are refrigerated to produce ice on the models like that encountered under certain flight conditions.

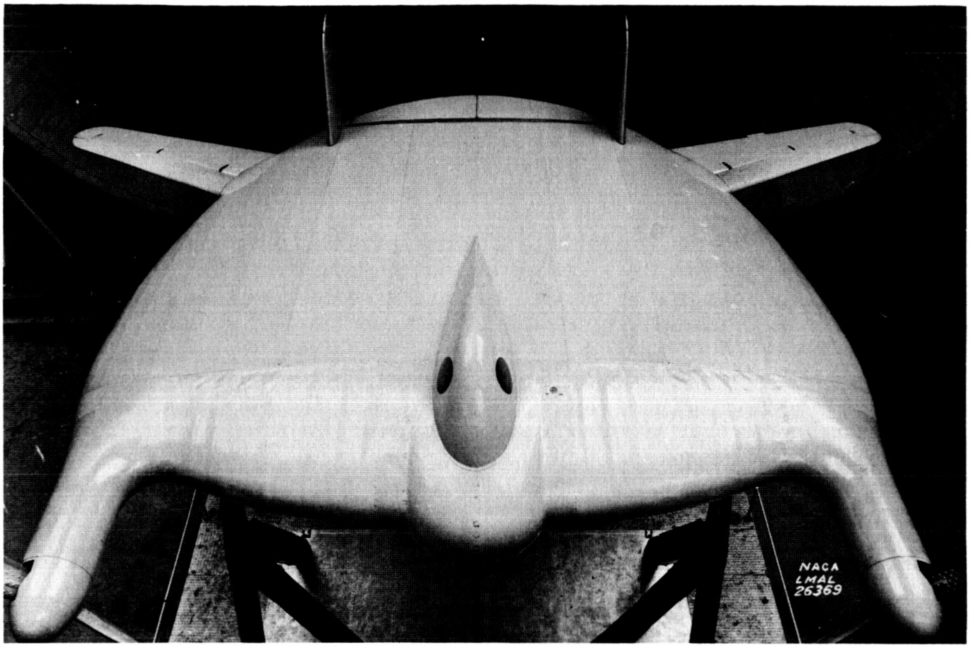


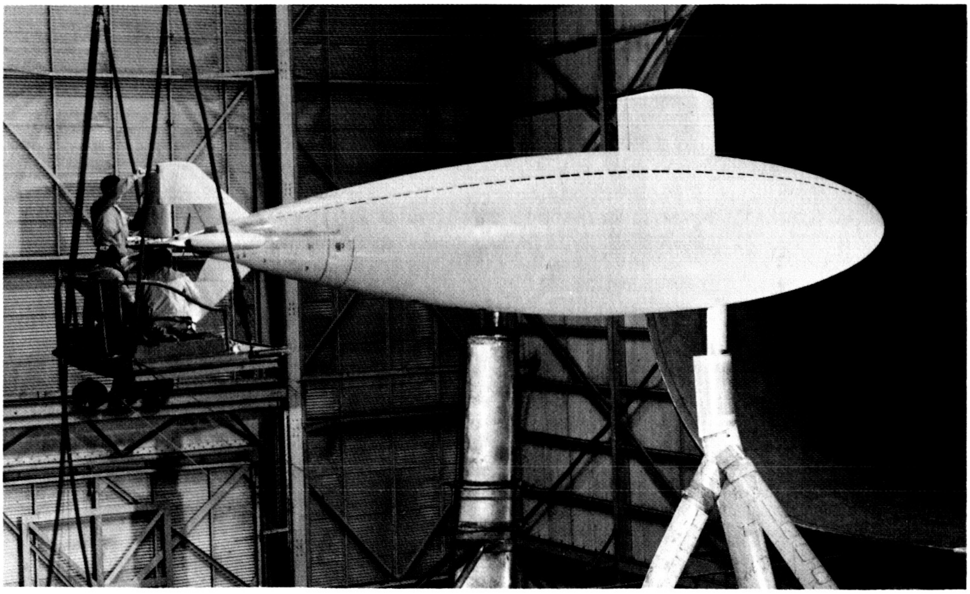
Aerial view of the Pilotless Aircraft Research Station, looking north along the Atlantic Ocean, in 1955. (LaRC)

In fact, wind tunnels have been designed to replicate nearly every condition encountered by airplanes in flight. There are vertical wind tunnels to study aircraft spinning characteristics, gust tunnels to determine the effect of fluctuations in the airstream, and curved-flow tunnels with variable geometry in the test section to determine flight characteristics in turns or maneuvers. There are even free-flight tunnels in which the model floats free and the test section cants to simulate different angles of attack.

The characteristics of a tunnel are not necessarily fixed permanently during construction. Many NACA tunnels saw long and varied service, upgraded to incorporate advances in wind-tunnel technology that adapted them to modern regimes of flight. The most frequent modification was repowering to produce higher velocities in the test section. Improved instrumentation and mountings were less dramatic but equally important.

The complexity of NACA tunnels—the vague distinction between a tunnel's basic equipment and the changing battery of auxiliary equipment that supported it, the shared housings and drive systems that many tunnels employed, and the repeated modifications that some tunnels underwent—makes it difficult to present a uniform picture of tunnel characteristics. Still more difficult to achieve is an accurate estimate of costs. The following lists contain the available data on the test section, circuit, speed,





So versatile and practical is the wind tunnel that it is called upon for all kinds of research tasks. Above, a mockup of the Vought-Sikorsky V–173, set up in Langley's full-scale wind tunnel in 1941. Below, a submarine model mounted in the same tunnel in the 1950s; since air and water have comparable flow characteristics, a boat's performance under water could be predicted in such tests. (LaRC) and drive systems of all major NACA tunnels. Cost information is not sufficiently reliable to merit inclusion, but one example will suggest the range of expenses involved. The first NACA wind tunnel (the 5-foot atmospheric tunnel built at Langley in 1920) cost about $45,000. The 10- by 10-foot supersonic tunnel built at Lewis in the early 1950s cost $35,000,000.

Research Facilities Other Than Wind Tunnels

The wind tunnel that dominated NACA research could not provide all the answers the Committee needed to solve the problems of flight. Over the years the NACA constructed other research laboratories, buildings, and equipment to answer questions not aerodynamic in nature. These facilities are especially hard to trace because they frequently had no building of their own but occupied space in office buildings that housed a number of research functions. No attempt has been made to inventory these facilities in the same detail as the NACA wind tunnels, but a list of major nontunnel facilities at Langley may indicate the great variety of NACA equipment. Langley had more of these facilities than any other laboratory or station.

Facility	Operational Date
NACA [Towing] Tank No. 1	1931
Aircraft Engine Research Laboratory	1934
Structures Laboratory	1940
Seaplane Impact Basin	1942
NACA Tank No. 2	1942
Helicopter Apparatus	1944
Aircraft Loads Building	1945
Aircraft Loads Calibration Laboratory	1945
Physical Research Laboratory	1945
Instrument Research Laboratory	1946
Pilotless Aircraft Research Laboratory	1946
Landing Loads Track	1955
High-Speed Hydrodynamics Facility	1956

Note the rapid tempo of expansion of facilities during World War II, a measure of the NACA's concentration on wind-tunnel research in the 1920s and 1930s. And compare the small number of these with the extensive family of tunnels described in the following section.

Langley Aeronautical Laboratory

5-Foot Atmospheric Wind Tunnel (NACA Wind Tunnel No. 1)
Test section: 5-foot diameter (1.52 m), closed-throat
Circuit/pressure: Nonreturn/atmospheric
Maximum speed: 40 m/sec (89 mph)
Drive system: 200-hp (149-kw) electric motor/fan
Operational date: 11 June 1920
Disposition: Dismantled in 1930
Notes: Modeled after an early tunnel at the National Physical Laboratory in Britain; primitive for its time.
References: F. H. Norton, "National Advisory Committee's 5-Foot Wind Tunnel," *Journal of the Society of Automotive Engineers* (21 May 1921): 1–7; TR-195, p. 208 (diagram)

Variable-Density Tunnel

Test section: 5-foot diameter (1.52 m), closed-throat
Circuit/ pressure: Annular return/20 atmospheres
Maximum speed: 23 m/sec (51 mph)
Drive system: 250-hp (187-kw) electric motor/fan
Operational date: March 1923
Disposition: Only pressure shell remains
Notes: Designed by Max Munk; proposed in 1921; converted to open-throat in April 1928 after damage to the original in fire of August 1927; returned to closed-throat design in major remodeling in Dec. 1930 because the open-throat arrangement did not work properly.
References: TRs-185, -227, -416

Propeller-Research Tunnel

Test section: 20-foot diameter (6.1 m), open-throat
Circuit/pressure: Double return/atmospheric
Maximum speed: 49.1 m/sec (110 mph)
Drive system: Two 1,000-hp diesel engines (746 kw each)/fan
Operational date: July 1927
Disposition: Dismantled in 1950 to make way for 8-foot Transonic Pressure Tunnel.
Notes: Proposed by Fred Weick; designed by Max Munk and Elton W. Miller; design and construction begun in 1925.
References: TR-300

5-Foot Vertical Wind Tunnel

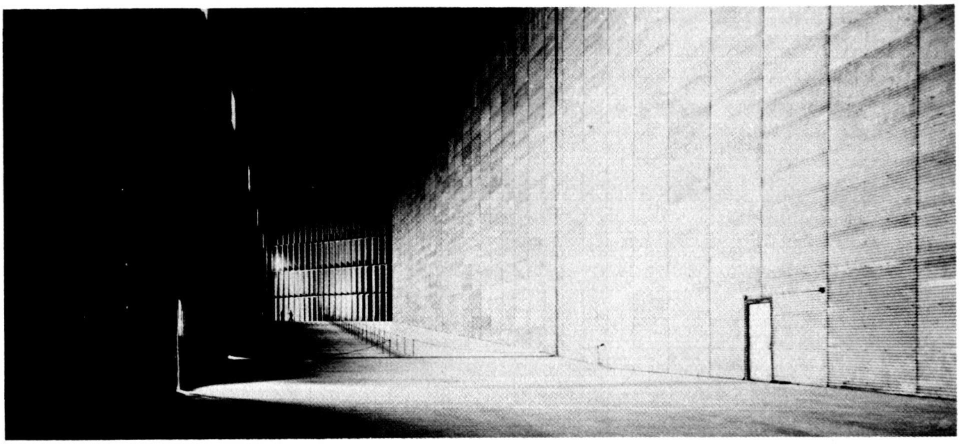
Test section: 5-foot-diameter (1.52 m), open-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 35.8 m/sec (80 mph)
Drive system: 50-hp (37.3-kw) electric motor/fan
Operational date: 1930
Disposition: Deactivated
Notes: Designed to investigate spinning characteristics; converted to 4- by 6-foot closed-throat configuration in 1938.
References: *AR 1930;* TR-387

Atmospheric Wind Tunnel (AWT) (7- by 10-Foot Wind Tunnel)

Test section: 7- by 10-foot (2m by 3m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 35.8 m/sec (80 mph)
Drive system: 200-hp (149-kw) electric motor/fan
Operational data: Summer 1930
Disposition: Deactivated
References: TR-412

Full-Scale Tunnel

Test section: 30- by 60-foot (9.1 x 18.3m), open-throat
Circuit/pressure: Double-return/atmospheric
Maximum speed: 57.2 m/sec (118 mph)



The view down the air-return passage in the Langley full-scale wind tunnel dwarfs two workers standing by the guide vanes. (LaRC)

Drive system: Two 4,000-hp (2,984 kw each) electric motors/fan
Operational date: Spring 1931
Disposition: Operational
Notes: Underwent major rehabilitation in 1977 with no change in performance.
References: TR-459

11-inch High-Speed Tunnel

Test section: 11-inch (0.3m) diameter, closed-throat
Circuit/pressure: Nonreturn/atmospheric
Maximum speed: M1
Drive system: Compressed air from variable-density tunnel; induction drive
Operational date: 3 March 1932
Disposition: See notes
Notes: Successor to the 12-inch open-throat tunnel designed in 1927 and operated 1928–1932.
References: TR-463

24-Inch High-Speed Tunnel

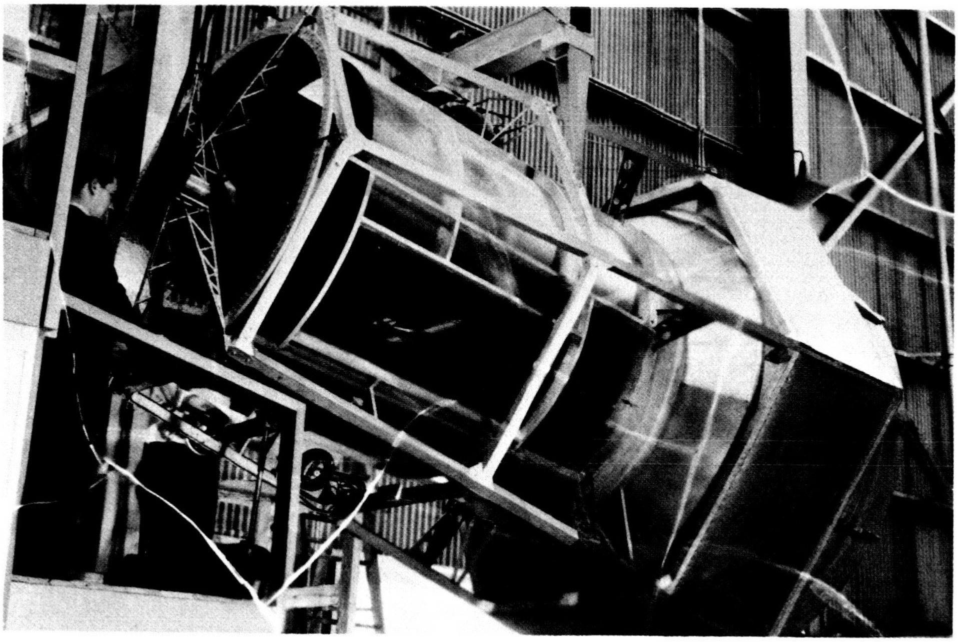
Test section: 24-inch (0.6m) diameter, closed-throat [3]
Circuit/pressure: Nonreturn, atmospheric
Maximum speed: M1
Drive system: Injector drive; blowdown from variable-density tunnel
Operational date: 3 October 1934
Disposition: See notes
Notes: Produced the first Schlieren photographs at LMAL; enclosure installed 29 Aug. 1949.
References: TR-646

15-Foot Spin Tunnel (15-Foot Free-Spinning Tunnel)

Test section: 15-foot diameter/open-throat; 12-sided polygon/closed-throat [2]
Circuit/pressure: Nonreturn/atmospheric
Maximum speed: 18 m/sec (40 mph), variable to rate of fall of aircraft model
Drive system: 150 hp[2]
Operational date: March 1935
Notes: Modeled on British tunnel of 1932.
References: TR-557; *Aero Digest* (June 1935): 20-22

8-Foot High-Speed Wind Tunnel

Test section: 8-foot-diameter (2.44 m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: M 0.75
Drive system: 8,000-hp (5968-kw) electric motor/fan
Operational date: March 1936
Disposition: Deactivated 1956
Notes: The only NACA tunnel with external concrete walls, constructed with WPA funds; repowered in Feb. 1945 to 16,000 hp, M 1 capability; slotted throat installed in 1950; increased to 25,000 hp in 1953 to yield M 1.2; the tunnel used to verify the area rule.
References: *AR-1936*



A researcher "flies" a model (center) in the Langley laboratory's 5-foot free-flight tunnel. (LaRC)

5-Foot Free-Flight Tunnel

Test section: 5-foot (1.5m) diameter
Circuit/pressure: Nonreturn/atmospheric
Maximum speed: 25 ft./sec. (7.6 m/sec)
Drive system: 5 hp (3.7 kw)
Operational date: 1937
Disposition: Replaced by 12-foot free-flight tunnel in 1939

Two-Dimensional Low-Turbulence Tunnel (Ice Research Tunnel)

Test section: 3- by 7.5-foot (0.9 m x 2.3 m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 69 m/sec (155 mph)
Drive system: 200-hp (149-kw) electric motor/fan
Operational date: April 1938
Disposition: Dismantled
References: TN-1283

19-Foot Pressure Tunnel

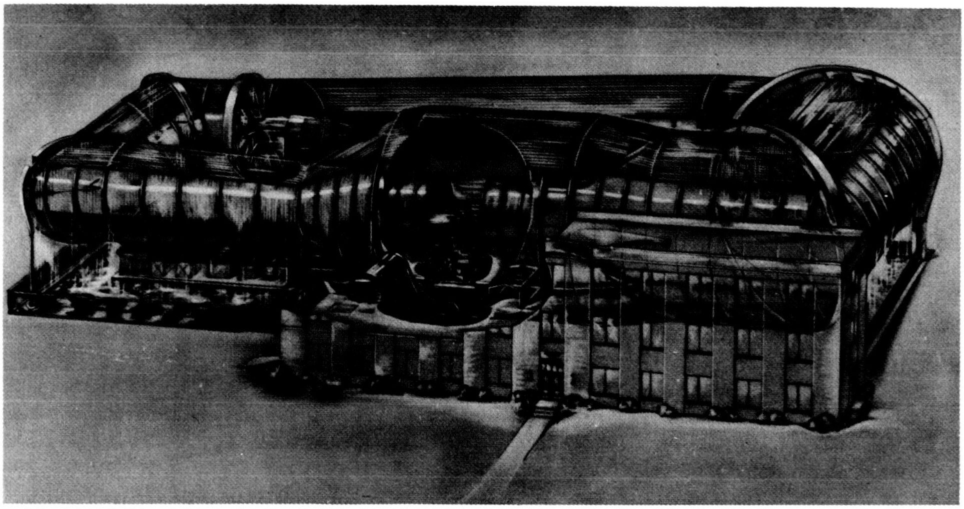
Test section: 19-foot (5.8 m) diameter, closed-throat
Circuit/pressure: Single return/0 to 40 psia (2.72 atm.)
Maximum speed: 330 mph (100 m/sec), atm. pressure
Drive system: 8,000-hp (5,968-kw) electric motor/fan
Operational date: December 1939
Notes: Designed by John F. Parsons under Smith J. DeFrance for high Reynolds-number research on problems of low-speed high-lift stability and control; converted to transonic dynamics tunnel in 1954.

12-Foot Free-Flight Tunnel

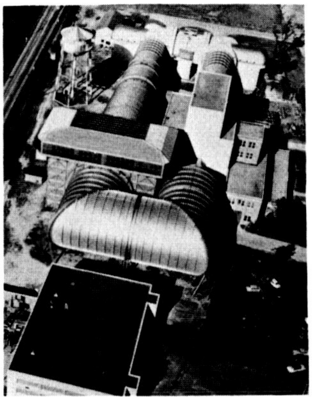
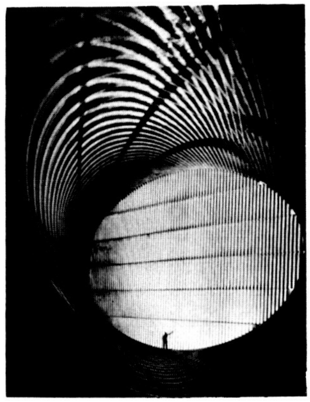
Test section: 12-foot (3.7 m) 12-sided $^{2}/8$-sided polygon[1]
Circuit/pressure: Annular return/atmospheric[1], 2 atm. (max.)
Maximum speed: 50 mph (15.2 m/sec)
Drive system: 600-hp (447-kw) electric motor/fan
Operational date: 1939
Notes: Undertaken in 1937 on the basis of success of the 5-foot free-flight tunnel; inclination and airspeed of tunnel matched to normal glide pattern of model.

Low-Turbulence Pressure Tunnel

Test section: 3- by 7.5-foot (0.9 x 2.3 m), closed-throat
Circuit/pressure: Single-return/150 psia
Maximum speed: M 0.22 to 0.45
Drive system: 2,000-hp (1,492-kw) electric motor/fan
Operational date: May 1941
Notes: Designed by Eastman Jacobs and Ira Abbott; operated briefly with freon gas as the test medium. Still operational.
References: TN-1283



Above, a phantom drawing of the Langley 19-foot pressure tunnel shows the test section at the front center, the turning vanes at the four corners, and the drive fan at the left rear. The air moves clockwise. Below, a technician mounts a model of Republic Aviation's F94F in the test section. (LaRC)

From the outside, Langley's 16-foot high-speed tunnel is an imposing but comprehensible building. Inside, however, is an awesome and beguiling world of shadows, deceptive scale, and optical illusions. Though the wind tunnel helps the researcher see flight more clearly, it also has the capacity to cause tunnel vision—to make the tool an end in itself. (LaRC)

20-Foot Spin Tunnel (20-Foot Atmospheric Free-Spinning Tunnel)

Test section: 20-foot (6.1 m), 12-sided, closed-throat
Circuit/pressure: Annular-return/atmospheric
Maximum speed: 0 to 30 m/sec (0 to 66 mph)
Drive system: 400-hp (298-kw) electric motor/fan (1,300 hp overload)
Operational date: March 1941
References: NACA L–86258

16-Foot High-Speed Tunnel

Test section: 16-foot diameter, closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: M 0.7
Drive system: 16,000 hp (11,936 kw) electric motor/single fan
Operational date: November 1941
Disposition: Operational as 16-foot transonic tunnel
Notes: Repowered in 1950 with 60,000-hp drive and 14-foot slotted test section (M 1.1); in 1969 added 35,000-hp plenum suction blower (M 1.3).

Stability Tunnel

Test section: Dual: 75-in (1.9 m) diameter; 6- by 6-foot (1.8 m) curved flow
Circuit/pressure: Single-return/atmospheric
Maximum speed: 56 m/sec (125 mph)
Drive system: 600-hp (447-kw) electric motor/fan
Operational date: June 1942
Disposition: Deactivated
Notes: Specially designed for testing in rotational and curved flow; transferred to Virginia Polytechnic Institute in 1958.
References: TN–2483

9-Inch Supersonic Tunnel

Test section: 9-in by 9-in (0.23 m x 0.23 m)
Circuit/pressure: Single-return,[1] nonreturn/atmospheric
Maximum speed: M 2.5
Drive system: 1,000 hp[1]
Operational date: July 1942, June 1943[1]
Disposition: Dismantled
Notes: Adjustable nozzle abandoned in favor of fixed nozzle.

Gust Tunnel

Test section: 8- by 14-foot (2.4 m x 4.3 m), open-throat[1]
Circuit/pressure: Nonreturn/atmospheric
Maximum speed: M 0.04 to 0.13[1]
Drive system: 75 hp[1]
Operational date: August 1945
Notes: Designed for research on aircraft loads produced by atmospheric turbulence.

Flutter Tunnel

Test section: 4.5-foot diameter, closed-throat[2]
Circuit/pressure: Closed-return/0 to 1.8 atmospheres[2]
Maximum speed: M 1[2]
Drive system: 1,000 hp[2], 1,400 hp[1]
Operational date: September 1945

300-Mph 7- by 10-Foot Tunnel

Test section: 7- by 10-foots (2.1 m x 3.1m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 134 m/sec (300 mph)
Drive system: 1,600-hp (1,193-kw) electric motor/fan
Operational date: February 1945
Disposition: Dismantled 1970
Notes: Two test sections: 7- by 10-foot—300 mph; 17- by 15.8-foot—8 mph.

High-Speed 7- by 10-Foot Tunnel

Test section: 7- by 10-foot (2.1 m x 3.1m), closed-throat
Circuit/pressure: Single-return/pressure
Maximum speed: M 0.9
Drive system: 14,000-hp (10,444-kw) electric motor/fan
Operational date: November 1945
Notes: Slotted test section installed, capability to M 1; connected to 35,000-hp compressor of 16-foot transonic tunnel for transonic operations, M 1.2.

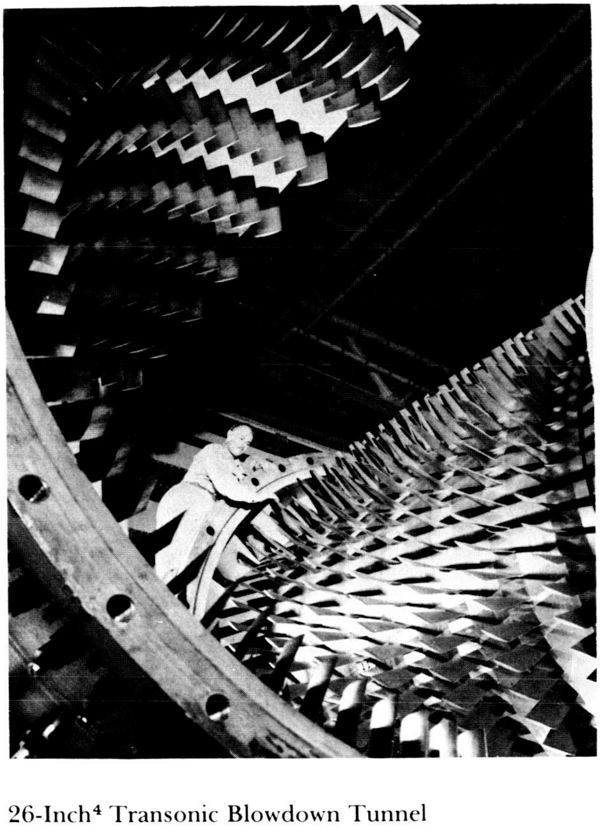
11-Inch Hypersonic Tunnel

Test section: 11- by 11-in (0.3 m x 0.3m)
Circuit/pressure: Nonreturn/540 psi max (36 atm)
Maximum speed: M 7

Drive system: Blowdown
Operational date: 1947
Notes: Proposed by John Becker as forerunner of supersonic tunnel; pilot model for 5–10 mach tunnel; electric resistance heater raised temperature in settling chamber to 900° F.

4- by 4-Foot Supersonic Tunnel

Test section: 4.5- by 4.5-foot (1.4 m x 1.4 m), template adjusted, flexible wall nozzles
Circuit/pressure: Single-return/subatmospheric
Maximum speed: M 1.25 to 2.2
Drive system: 6,000-hp (4,476-kw) electric motor/fan
Operational date: 20 May 1948
Disposition: Dismantled 1977
Notes: Repowered in August 1950 to 45,000-hp, 2.5 atmospheres pressure, M 2.6.



With the stationary housing blades removed, a technician inspects the rotor blades of the compressor in Langley's 4-foot supersonic wind tunnel. (LaRC)

26-Inch[4] Transonic Blowdown Tunnel

Test section: 26-in octagon
Circuit/pressure: Nonreturn/7 atm (max)
Maximum speed: M 0.6 to 1.45
Drive system: Blowdown
Operational date: 1950

Disposition: No longer operational
Notes: Blowdown from low-turbulence pressure tunnel, 150 psi.

Gas-Dynamics Laboratory (Hypersonic Aerothermal-Dynamics Facility)

Test section, circuit/pressure, maximum speed, drive system: Central 3,000 psi (204 atm) tank farm provides heated air to several small blowdown tunnels. M_{max} with air is 8.
Operational date: 1951
Disposition: Operational. High-pressure nitrogen and helium supply also available

8-Foot Transonic Pressure Tunnel

Test section: 7.1- by 7.1-foot (2.2 m x 2.2 m), slotted-throat
Circuit/pressure: Single-return/0.1 to 2.0 atmospheres
Maximum speed: M 0.2 to 1.2
Drive system: 25,000-hp (18,650-kw) electric motor/fan
Operational date: 1953
Notes: Plenum suction added in 1958 increased speed to M 1.3.

Unitary 4- by 4-Foot Supersonic Tunnel

Test section: 4- by 4-foot (1.2 m x 1.2 m)/asymmetric nozzle
Circuit/pressure: Single-return/150 psia
Maximum speed: M 1.5 to 4.6
Drive system: 83,300-hp (62,140-kw) electric motor/4 compressor units
Operational date: 1955
Notes: Two separate test sections: low, M 1.5 to 2.9; high, M 2.3 to 4.6.

9- by 6-Foot Thermal Structures Tunnel

Test section: 8.75- by 6-foot (2.7 m x 1.8 m), solid wall
Circuit/pressure: Nonreturn/50 to 200 psia (3.4 to 13.6 atm), 300 to 660°F (149 to 349°C)
Maximum speed: M 3
Drive system: Blowdown from 600 psia tank farm
Operational date: September 1957
Disposition: Deactivated 30 September 1971
Notes: Running time was 75 sec at 50 psia, 18 sec at 200 psia; hot core capability added in 1963 by propane burning; closed by rupture of 600-psia tank farm in 1971.

20-Inch Hypersonic Tunnel

Test section: 20-in diameter
Circuit/pressure: Nonreturn
Maximum speed: M 6
Drive system: Blowdown
Operational date: 1958
Disposition: Operational
Notes: A workhorse tunnel for inlets and complete models.

Ames Aeronautical Laboratory

7- by 10-Foot Tunnel Nos. 1 and 2
Test section: 7- by 10-foot (2.1 m x 3.1 m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 112 m/sec (250 mph)
Drive system: 1,800-hp (1,343-kw) electric motor/fan
Operational date: No. 1: March 1940; No. 2: July 1940

16-Foot High-Speed Tunnel

Test section: 16-foot (4.9 m) diameter, closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: M 1
Drive system: 27,000-hp (20,142-kw) electric motor/fan
Operational date: December 1941
Notes: Repowered in 1955 to 110,000 hp (82,060 kw) with 14- by 14-foot (4.3 m x 4.3 m) transonic test section, M 1.2.

40- by 80-Foot Wind Tunnel

Test section: 40- by 80-foot (12.2 m x 24.4 m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 103 m/sec (230 mph)
Drive system: Six 6,000-hp (4,476-kw) electric motors/fan
Operational date: June 1944
Notes: Power increased in 1979 to 135,000 hp (100,710 kw), M 45; 80- by 120-foot leg (24.4 m x 36.6 m) added.

1- by 3.5-Foot High-Speed Tunnel

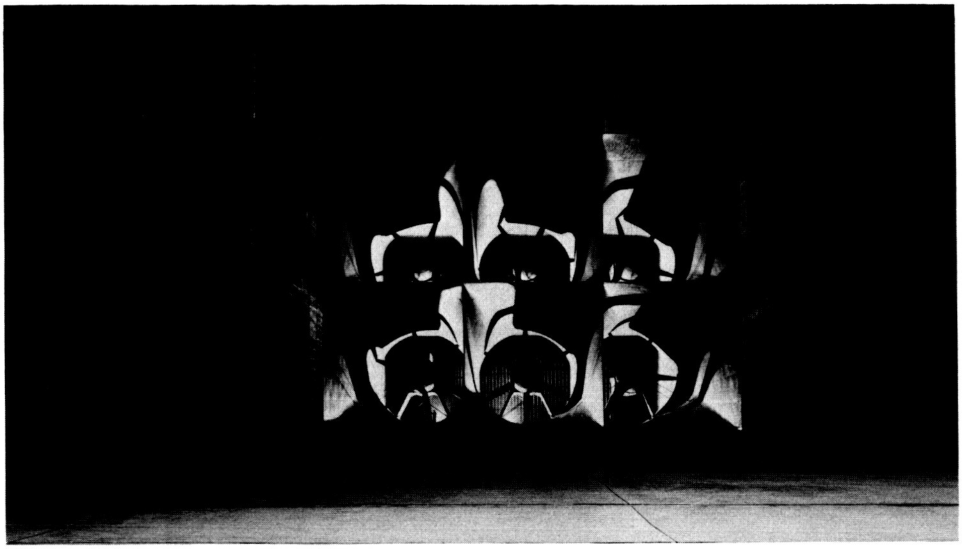
Test section: 1- by 3.5-foot[1] (0.3 m x 1.1 m)
Circuit/pressure: Closed-circuit[1]/atmospheric[2]
Maximum speed: M 1.2[1]
Drive system: 2,000 hp[1] (1,492 kw)
Operational date: January 1944

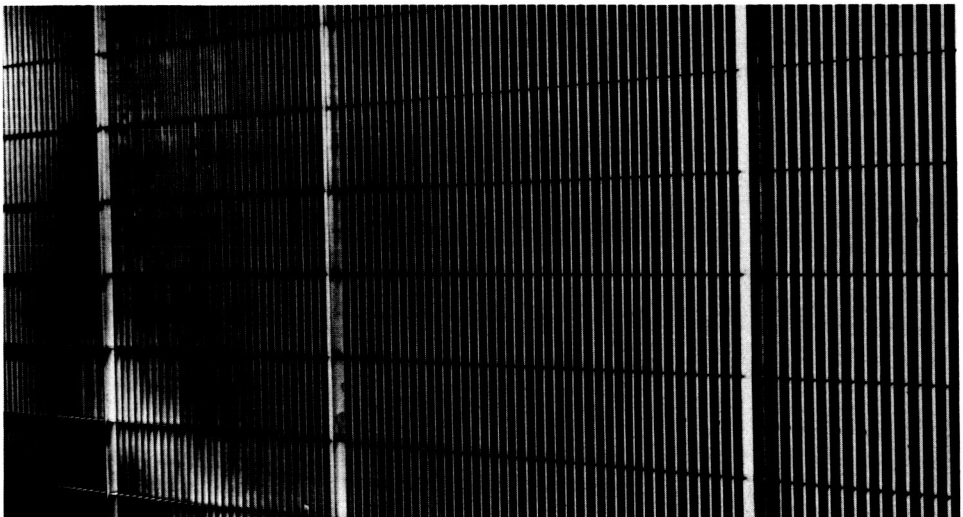
1- by 3-Foot Supersonic Tunnel

Test section: 1- by 3-foot (0.3 m x 0.9 m)
Circuit/pressure: Closed-circuit[1]/4 atm
Maximum speed: M 1.4 to 2.2[1]
Drive system: 11,500 hp[1] (8,579 hp)
Operational date: 1946

12-Foot Pressure Tunnel

Test section: 12-foot (3.7 m) diameter, closed-throat
Circuit/pressure: Single-return/0.2 to 5 atmospheres
Maximum speed: M 0.98
Drive system: 12,000-hp (8,952-kw) electric motor/fan
Operational date: July 1946
Notes: Exceptionally low turbulence level.





The size of the Ames 40- by 80-foot full-scale wind tunnel is evident in these two internal photographs. Above, an automobile parked inside the tunnel (above) is about the size of each of the six motors that power the airflow. A man stands beside one of the propeller blades of the lower left mount. Below, turning vanes in the tunnel tower over two workers on the tunnel floor. (ARC)

6- by 6-Foot Supersonic Tunnel

Test section: 6- by 6-foot (1.8 m x 1.8 m), sliding block asymmetric nozzle
Circuit/pressure: Single-return/0.3 to 1 atmosphere
Maximum speed: M 1.3 to 1.8 (continuously variable)
Drive system: 60,000-hp (44,760-kw) electric motors/2 compressors
Operational date: 16 June 1948
Notes: Modified in 1956 to provide subsonic/transonic capability, M 0.3 to 2.2.

Supersonic Free-Flight Tunnel

Test section: 1- by 2-foot closed-throat
Circuit/pressure: Nonreturn/6 atmospheres
Maximum speed: M 2; gun velocity, 1,000 to 6,000 ft. sec (305 to 1,829 m/sec), M_{rel} 2 to 10
Drive system: Compressor system from 12-foot pressure tunnel
Operational date: 1949
Notes: Projectile fired upstream; produces shadowgraphs.
Reference: TR-1222

2- by 2-Foot Transonic Tunnel

Test section: 2- by 2-foot (0.6 m x 0.6 m) /ventilated wall
Circuit/pressure: Single-return/0.2 to 3 atm
Maximum speed: M 0.2 to 1.4
Drive system: 4,000-hp (2,984-kw) electric motor
Operational date: 1951
Reference: NASA SP-4302

Unitary 11- by 11-Foot Transonic Tunnel

Test section: 11- by 11-foot (3.6 m x 3.6 m), slotted wall
Circuit/pressure: Single-return/0.5 to 2.25 atmospheres
Maximum speed: M 0.7 to 1.4
Drive system: 180,000-hp (134,280-kw) electric motor/3-stage fan
Operational date: 1955
Notes: Drive motors shared with supersonic legs.

Unitary 9- by 7-Foot Supersonic Tunnel

Test section: 9- by 7-foot (2.7 m x 2.1 m), asymmetric nozzle
Circuit/pressure: Single-return/0.3 to 2 atmospheres
Maximum speed: M 1.55 to 2.5
Drive system: 180,000-hp (134, 280-kw) electric motor/11-stage compressor
Operational date: 1955
Notes: Common drive leg with 8- by 7-foot supersonic tunnel; drive motors shared with transonic leg.

Unitary 8- by 7-Foot Supersonic Tunnel

Test section: 8- by 7-foot (2.4 m x 2.1 m), symmetrical flexible wall
Circuit/pressure: Single-return/0.3 to 2 atmospheres
Maximum speed: M 2.5 to 3.5
Drive system: 180,000-hp (134,280-kw) electric motor/11-stage compressor
Operational date: 1955
Notes: Drive leg shared with 9- by 7-foot supersonic tunnel; drive motors shared with transonic leg.

10- by 14-Inch Hypersonic Tunnel

Test section: 10- by 14-in (0.3 m x 0.4 m), closed-throat, variable-geometry supersonic nozzle
Circuit/pressure: Nonreturn/6 atmospheres
Maximum speed: M 2.7 to 6.3
Drive system: Existing compressors from 12-foot pressure tunnel
Operational date: 1950
Notes: Low-energy start via double-hinged fixed-contour nozzle blocks; boundary layer control at second throat.
Reference: TN 3095

14-Foot Transonic Tunnel

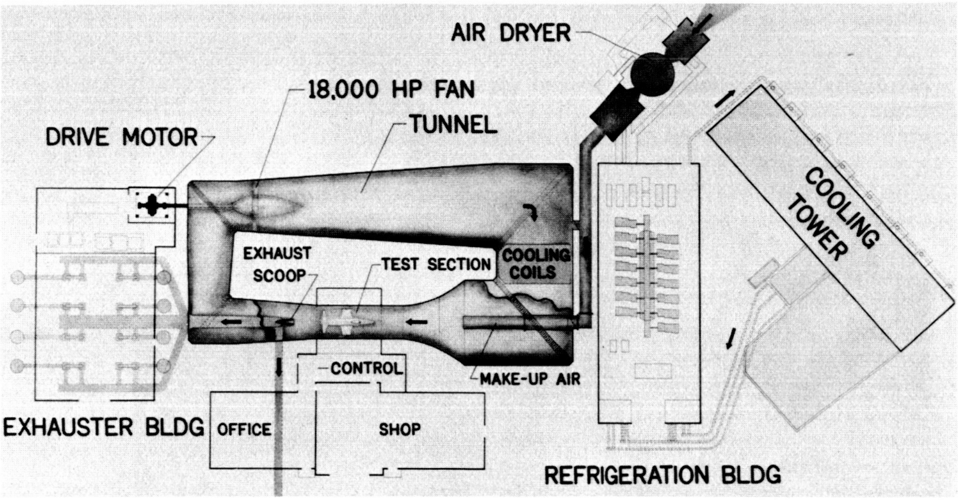
Test section: 13.5- by 13.7-foot (4.1 m x 4.2 m), perforated wall
Circuit/pressure: Single-return/ atmospheric
Maximum speed: M 0.6 to 1.2
Drive system: 110,000-hp (82,060-kw) electric motor/3-stage fan
Operational data: 1956
Notes: Adjustable flexible-wall nozzle ahead of test section.

1-Foot Hypervelocity Tunnel

Test section: 1-foot diameter
Circuit/pressure: (Not applicable)
Maximum speed: M 10
Drive system: 60,000-hp (44,700-kw) electric motor
Operational date: 1957
Disposition: Demolished in 1972
Notes: Run duration, 180 milliseconds; converted in 1967 to 42-in. shock tunnel.
References: TN D-1428

Lewis Flight Propulsion Laboratory

Altitude Wind Tunnel
Test section: 20-foot (6.1 m) diameter, closed- or open-throat
Circuit/pressure: Single-return/0.1 to 1 atmosphere
Maximum speed: 224 m/sec (500 mph) at altitude conditions
Drive system: 18,000-hp (13,428-kw) electric motor/fan
Operational date: 1944
Disposition: Deactivated 1958
Notes: Designed for altitude propulsion-system testing; used after 1958 as a rocket test cell.



Schematic diagram of the altitude wind tunnel and associated facilities at the Lewis laboratory. (LeRC)

Icing Research Tunnel

Test section: 6- by 9- foot (1.8 m x 2.7 m), closed-throat
Circuit/pressure: Single-return/atmospheric
Maximum speed: 134 m/sec (300 mph)
Drive system: 4,160-hp (3,103-kw) electric motor/fan
Operational date: 1944
Notes: 2,100-ton refrigeration system cools tunnel air to −40°F (4°C): water sprays provided.

8- by 6-Foot Supersonic Tunnel

Test section: 8- by 6-foot (2.4 m x 1.8 m), flexible-wall nozzle, perforated[4]
Circuit/pressure: Nonreturn/maximum pressure 1.75 atmospheres at M 2
Maximum speed: M 1.4 to 2.0
Drive system: 87,000-hp (64,900-kw) electric motors/7-stage axial flow compressor
Operational date: 1949
Notes: Converted to open/closed return; added transonic section and vertical takeoff and landing section. M 0.36 to 2.0 (primary test section).

Unitary 10- by 10-Foot Supersonic Tunnel

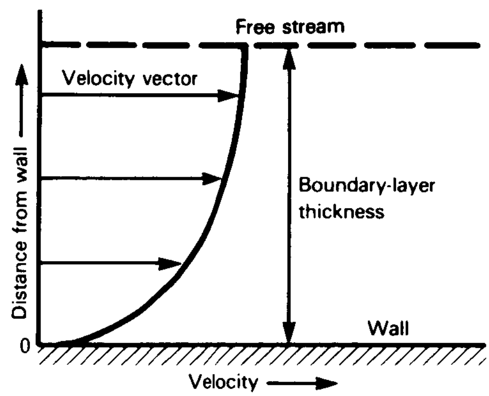
Test section: 10- by 10-foot (3.1 m x 3.1 m), symmetric nozzle
Circuit/pressure: Return or nonreturn
Maximum speed: M 2.0 to 3.5
Drive system: 250,000-hp (186,500-kw) electric motors/fan
Operational date: 1955
Notes: Designed for propulsion-system testing; can be run open to the atmosphere.
References: TM X-71625

Appendix F
Research Authorization 201

This is the story of an NACA research authorization. It tells how and why the authorization was opened, executed, and closed. While research authorization 201 had some idiosyncrasies—it lasted longer than most and produced fewer practical results—still it is sufficiently representative to give some idea of how the NACA went about aeronautical research. It is particularly enlightening on the respective roles of headquarters and the laboratory in selecting and conducting research projects, on changes in those roles over the years, on publication policies of the Committee, and on the relations of NACA staff members with clients and colleagues.

Boundary-layer research had been going on in Europe for 20 years before the NACA took any official interest. Only when the Europeans began to achieve some success in boundary-layer *control* did the NACA launch a program of its own. The NACA was always more interested in application than in theory; it never wanted to understand the wind so much as to control it.

The boundary layer is a thin film that forms on the surface of a solid body moving through a viscous fluid, like the wing of an airplane moving through the air. Within the film, velocity increases parabolically, from zero at the solid surface up to the free-stream velocity at the outer edge of the boundary layer. The depth of the layer varies with the smoothness of the surface, the viscosity of the fluid, and the speed of the flow, but it is never very large. At 5 cm from the leading edge of a flat plate moving through standard sea-level air at zero angle of incidence and 120 m/sec, the boundary layer will be only .04 cm deep.[1]

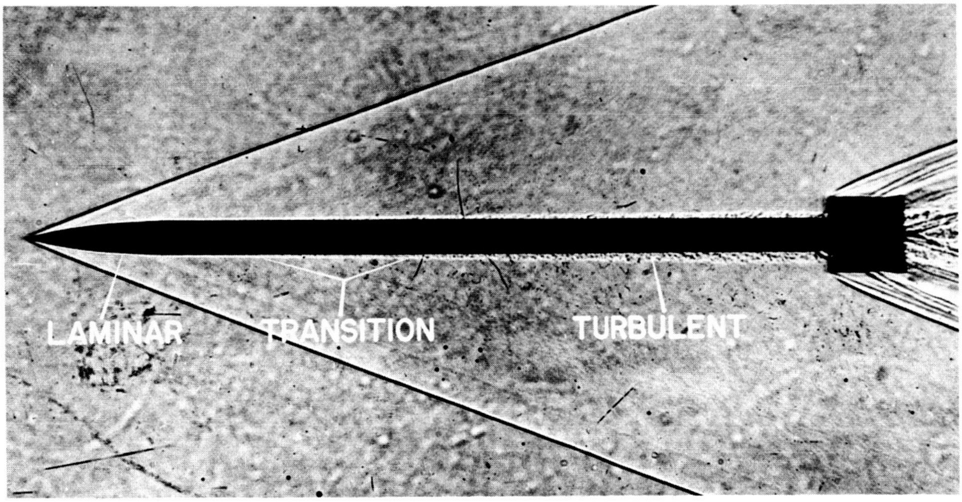


Profile of a boundary layer. (NASA EP-89, 1971, p. 68)

The boundary layer was first identified and labeled by Ludwig Prandtl in 1904 in a classic paper that revolutionized this branch of fluid mechanics. The Göttingen University professor actually used the term "boundary layer" only once, while he used "transition layer" seven times. But "boundary layer" became the accepted term, and boundary-layer theory became the descriptor of choice for the entire field. Prandtl had based his paper on empirical investigations, but his concept remained only a theory until it was verified in the 1930s and 1940s by more sophisticated research instruments and techniques. Even today, some of the more complex behavior of the boundary layer is explained only by unconfirmed theory.[2]

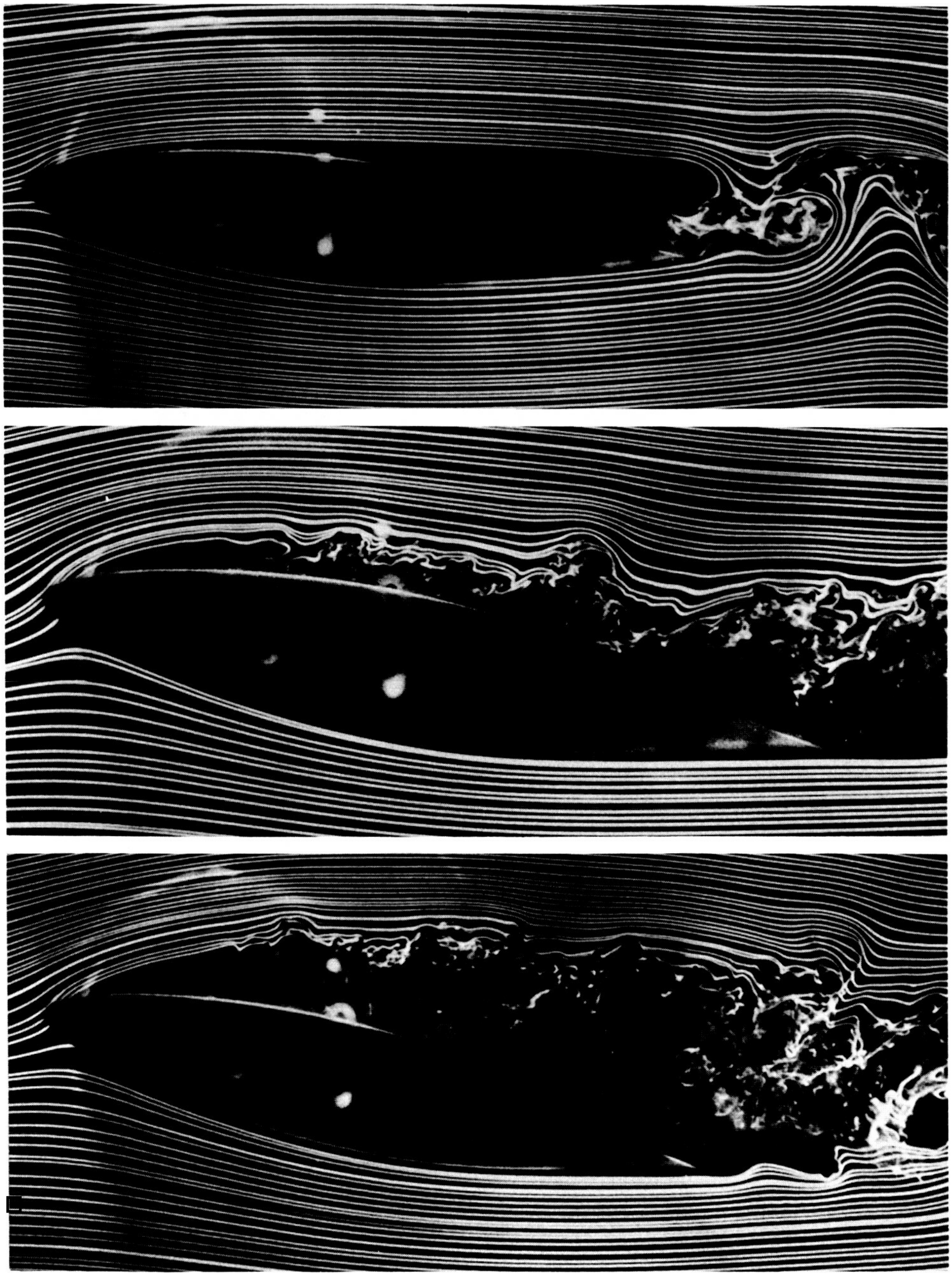
Applications of boundary-layer reserarch are as diverse as the circumstances of fluid flow itself. Prandtl was studying the use of a jet of air to blow away sweepings in a factory. Others looked into the flow of fuids in pipes. Many turned their attention to the infant technology of flight, seeking to improve the flow of air over wings.

The flying qualities of wings can be enhanced in two ways, and boundary-layer control can help in both. The first is to decrease drag, the second is to increase lift. The most desirable way to decrease drag is to maintain laminar flow within the boundary layer and prevent a transition to turbulent flow. Laminar flow occurs when successive layers of air within the boundary layer slide smoothy over one another, from the stationary film at the surface up to the free-stream velocity of the outside air. Turbulent flow within the boundary layer occurs when these "streamlines break up and a fluid element moves in a random, irregular, and tortuous fashion," as when the smoke rising from a cigarette in a still room ceases to travel smoothly up but tumbles instead in eddies and curls. Over a normal wing, the boundary layer remains laminar over only a small portion of the wing chord before breaking up into turbulent flow. The area of turbulent flow experiences significantly greater skin-friction drag than the laminar flow.[3]

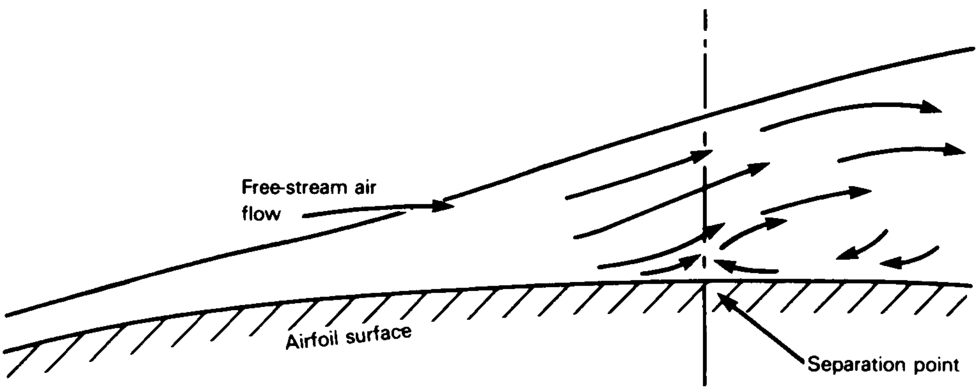


Transition from laminar to turbulent flow can be seen occurring down the length of this missile-body model captured by shadowgraph in high-speed flow. (ARC)

The second way to improve the flying qualities of a wing through boundary-layer control is to increase the lift, especially the maximum lift, of the wing. Maximum lift can be increased by delaying the onset of separation of the boundary layer. As a wing's angle of incidence increases—as its leading edge is tipped up above the plane of flow of the



This smoke-flow visualization of the same wing at differing angles (6°, 12°, 14° top to bottom) of incidence reveals how tipping a wing above the plane of flow can bring on separation of the boundary layer, and stalling. (LaRC) free-stream air—its lift also increases, up to a point. Finally, however, the boundary layer on the upper surface breaks free of the wing altogether, reducing lift drastically. This is known as stalling. If the boundary layer can be kept from separating, the maximum lift of the aircraft can be increased, an important consideration in increasing takeoff-weight capacity and reducing landing speed. Furthermore, the same energizing of the boundary layer that delays separation can also help to maintain the boundary layer in fast laminar flow, increasing total lift even at low angles of incidence.



Separation of the boundary layer. (NASA TN-1384, 1947)

In the early years of boundary-layer theory, two methods of boundary-layer control were proposed by the Europeans, who dominated the field. Prandtl and his proteges at Göttingen developed mechanisms to suck the boundary layer along the upper surface of wings, thus maintaining laminar flow and preventing separation. Others studied ways of blowing air into the boundary layer near the leading edge, to energize the boundary layer and prevent separation.

The latter technique, with its promise of practical application, first drew the NACA into boundary-layer research. In 1926, Elliot G. Reid, a junior aeronautical engineer and a member of the Langley Memorial Aeronautical Laboratory's research council, wrote to the engineer-in-charge of the laboratory about European work in boundary-layer control. He noted that the research of Handley-Page and Lachmann in England "constituted the first successful attempt to control flow in the boundary layer," thus improving the performance of wings. He cited NACA Technical Memorandum 374, published just that year, describing the work of the Göttingen group under Prandtl. And, most important, he referred to John J. Ide's recent visit to Vienna, where the NACA's European representative had talked with Richard Katzmayr, director of the Vienna Aerodynamical Laboratory. Katzmayr was trying to increase lift by blowing compressed air over the upper surface of airfoils, and had already published some promising results. He gave Ide an extremely optimistic account of his work to date. On the basis of Ide's report, Reid suggested that the NACA Aerodynamics Committee should authorize "Experiments on Airfoils with Modified Boundary Layer Flow," looking into Katzmayr's blowing technique as well as the obverse method, the suction technique advocated by the Göttingen group.[4]

Reid's proposal immediately fell foul of the bureaucracy both at the laboratory and at headquarters in Washington. It was first forwarded for comment to Max Munk. Munk, the *enfant terrible* of the NACA, was a brilliant and temperamental aerodynamicist who had done more than anyone to set up the program and facilities of the Langley laboratory and to distinguish the NACA by important contributions to aeronautics. Just now he was in charge of the Aerodynamics Division, and he resented an outsider from the Engine Research Division suggesting programs for his fiefdom. "I suggest that Mr. E. G. Reid be advised to draw his memorandum back," he replied icily, "and to ask it to be forwarded to the Aerodynamics Division, if he cares to." [5] Apparently Reid did not care to, trying instead an end run around Munk directly to the NACA Aerodynamics Committee. That ploy brought him into collision with George W. Lewis, the NACA director of aeronautical research. Lewis advised the laboratory on 11 November—just one week after Munk's rebuff of Reid—that in the future all research recommendations would go through the Director of Aeronautical Research and would not be proposed directly to a technical committee or subcommittee.[6]

The engineer-in-charge duly forwarded Reid's recommendation to Lewis, with a copy to Munk. Munk's response, now more formal, displayed the temperament that would finally undo him at Langley:

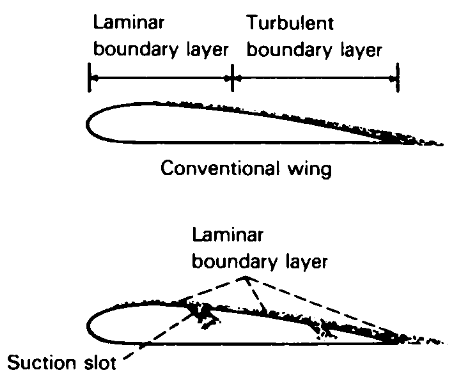
> Each problem should recieve [sic] the fullest amount of thought and interest and should be carried through as far as can be. Otherwise, we might degenerate into a mere test factory. From this point of view it is desirable to have only as many problems being turned over from outside as absolutely necessary. It is further desirable that each staff member propose chiefly such new problems as are derived directly from the problem he is engaged in at the time. Otherwise, the conclusion can not be avoided that he does not concentrate his entire mind on his problem; and furthermore, he is less prepared to know about the desirability of his proposed problem, if it does not belong to his present work in investigating.
>
> To sum up, we need on the side of our staff members the serious will and the intense interest necessary to solve problems, rather than reflecting on new problems to be solved by someone else.[7]

Part of this argument was mere selfserving rationalization, an attempt by Munk to keep his own field inviolate and to have the last word on what was done within it. To this extent it is petty and at odds with the way the Langley staff operated at its best—encouraging a free flow of ideas and suggestions and cutting across administrative boundaries as the demands of aeronautical research dictated. But Munk's argument contained a kernel of truth, and the investigation of boundary-layer control by the NACA might have proved more successful had Munk's advice been taken. Like all complex research activities, aeronautical research requires an informed supervisor able to see the big picture, to distinguish the forest from the trees, to separate the random interesting idea from the cumulatively productive next step in a long-term investigation. Reid's suggestion, though full of interest and potential, still bore no guarantee that it would prove the best way to use the limited personnel and facilities available to the NACA.

The engineer-in-charge sent Munk's comments along to George Lewis. For two weeks nothing happened. Then, on 3 December, Lewis sent Langley new photographs and test results from Katzmayr and directed the lab to check them in the atmospheric wind tunnel, earliest and crudest of the tunnels then at Langley. The laboratory staff may have considered this a tentative approval of Reid's suggestion, but the real source of this authorization apparently was in Washington. On the previous day, Captain E. S. Land, assistant chief of the Navy's Bureau of Aeronautics, had formally requested that the NACA test in a wind tunnel and in flight the Katzmayr method of increasing lift.[8] Land was then one of two Navy members of the NACA Main Committee, a member of the Executive Committee, and a frequent visitor to the NACA offices. George Lewis may well have asked him if the Navy were interested in checking out Katzmayr's claim. The lower takeoff and landing speeds resulting from improved lift could appreciably help the Navy in its early attempts at carrier aviation.

Whether through collaboration or not, on 6 December Lewis forwarded Land's letter for comment to Langley with a revealing postscript: "A research authorization (No. 201) will be submitted to the Executive Committee for approval at its next meeting to carry out this request of the Bureau of Aeronautics." [9] In other words, Lewis might hesitate to submit laboratory recommendations to the Executive Committee—especially when opinion in the Langley staff was divided—but as soon as he had a Navy request in hand he had a research authorization in draft. Capt. Land's letter added nothing to the technical justification for the research, but it did add the political justification Lewis seems to have felt he needed.

While Langley was waiting for the Executive Committee to act on the proposal, the staff agreed in conference on the desirability of investigating Katzmayr's scheme as well as the suction method of boundary-layer control recently demonstrated by Theodore von Kármán, one of Prandtl's most accomplished proteges.[10] Flight testing and research in the atmospheric wind tunnel were prescribed, should research be authorized. Meanwhile, Katzmayr had visited Ide and provided full blueprints of his invention, which were duly forwarded through Lewis to Langley. Thereafter Katzmayr persistently sought word of NACA results, especially of comparing his blowing method with the suction method proposed by his rivals at Göttingen. Ide was eager to give him the information in return for his cooperation, but the Langley personnel at first reported "indefinite" results because of the "contradictory nature of the data" submitted by Katzmayr. By the middle of the following year, they were viewing the suction method as more promising, though before they reached a firm conclusion they wanted to know how Katzmayr had achieved the high pressures he claimed. At that juncture, Katzmayr disappears from the records.[11]



Above, transition from laminar to turbulent flow on a conventional wing; below, maintenance of laminar flow along the entire wing surface through use of suction slots. (NASA EP-89, 1971, p. 76)

While this modest investigation was proceeding, Lewis won the endorsement he had promised the laboratory on 6 December. Research Authorization 201, "Investigation of Various Methods of Improving Wing Characteristics by Control of the Boundary Layer," was approved by the Executive Committee and signed by its new chairman, Joseph Ames, on 21 January 1927. Broad as the title of the authorization was, its "Why" and "How" sections made it all too specific. The purpose of the investigation was to "Determine the possibilities of improving wing characteristics" by using the blowing and sucking methods suggested by Katzmayr and by the University of Göttingen respectively. The Katzmayr method was to be tested in the atmospheric wind tunnel and in flight, the Göttingen method only in the wind tunnel. Under "Remarks" it was noted: "Investigation requested by Bureau of Aeronautics."

With the research authorization in hand, the Langley staff offered a spate of suggestions: Max Munk suggested rounding the trailing edge of a wing as a means of controlling the boundary layer, and requested "that priority of this invention be taken down for the writer for a future application for a patent." The engineer-in-charge forwarded this suggestion with a note that it could be readily incorporated in the program for the atmospheric wind tunnel; this procedure was quickly approved by the Executive Committee and charged to research authorization 201. E. G. Reid, who at the beginning of this story had suffered at Munk's hands, now turned the tables by asking Munk to describe in a memo just exactly what he was recommending. When Munk failed to reply, the engineer-in-charge put the same question to him in writing. Still no answer. At last—apparently after a personal interview—the engineer-in-charge recorded formally on his own memo: "Dr. Munk has no suggestion to make." These were Munk's last days at the NACA, and this behavior was typical of the animosity and friction between him and the staff that made his departure inevitable.[12]

Suggestions by other members of the Langley staff fared better. A laboratory assistant recommended investigation of "electrical lubrication"— electrically charging the wing, with the expectation that the adjacent air would take on the same charge and be repelled, thus repelling the boundary layer and eliminating skin-friction drag altogether. Although entirely unrelated to the blowing and sucking methods specified in the research authorization, this idea won quick approval from the Executive Committee. Three other engineers recommended that research on the suction method proposed by Göttingen and reported in NACA TMs 374 and 395 be conducted in the variable-density wind tunnel. This newest tunnel, the brainchild of Max Munk, was the NACA's first radical research tool, a device for getting results more closely approximating those of an airplane in flight (see chapter 4). Though this too was a departure from the orginal specifications of research authorization 201—which had called for research in the atmospheric wind tunnel—the Executive Committee nonetheless gave it similarly quick endorsement.[13]

If a pattern was emerging here, it consisted of cautious NACA approval of a basic research authorization, preferably based on a specific request from one of the military services, followed by ready endorsement of laboratory suggestions on how to conduct the research. The Committee approved new ideas from all professional members of the staff (Munk's objections notwithstanding) and had no apparent compunction about straying from the precise language of the authorization. The authorization served rather as a foundation on which the laboratory, with the approval of Lewis and the Executive Committee, could build a program of its own choice.

First hard results of this particular investigation were disappointing. Thomas Carroll's report on "Preliminary Flight Tests of a Method of Boundary Layer Removal," submitted 2 September 1927, concluded that "the improvement in performance is negligible" for the first arrangement of sucking slots that the staff tried on an aircraft wing. One of the engineers quickly cautioned the engineer-in-charge not to publish these results, because they were for one method of installation only; circulation of the report, he warned, "might make persons less familiar with the subject skeptical of any possible improvement in wing characteristics by boundary layer control." The engineer-in-charge concurred and advised headquarters not to publish the report, as other wind-tunnel tests then underway might suggest better arrangements.[14]

In spite of this tendency to play their cards close to the vest, the Langley staff was already amassing a useful store of knowledge. In October 1927, less than a year after work on this research authorization began, J. S. McDonnell, Jr.—then a struggling young engineer in private employ, later to become one of the giants of the aircraft-manufacturing industry—wrote to ask if the NACA was doing research on the blowing and sucking methods of boundary-layer control such as that reported from Göttingen in the NACA TMs or from the Army's McCook Field in the *Journal of the Society of Automotive Engineers.* H.J.E. Reid was able to reply that the laboratory's research to date indicated that overall efficiency increased with use of suitable slots, that suction was more economical than blowing, and that a blunt nose on the airfoil appeared better than a sharp one. These results were worth publishing, and Reid in fact stated that the NACA was preparing a preliminary report that would include "a complete bibliography which may be considered as a guide to the work done on this subject by other research organizations."[15] Though the NACA was not itself publishing preliminary results, it was apparently following very closely the results published by other laboratories.

Another year was to elapse before the NACA actually published its first report under this research authorization. In the meantime it embarked on several new departures. In January 1928 George Lewis wrote the laboratory that in a recent conversation with Orville Wright, then a member of the NACA Main Committee, the pioneer aviator told of experimenting with a wing having a split trailing edge. This produced a considerable negative pressure along the line of the split; at high angles of attack it was possible that openings from the split to the interior of the wing could suck air into the wing and perhaps control the boundary layer. Lewis directed—apparently on the basis of this conversation alone—that Wright's concept be included in the work done under research authorization 201.[16]

Henry J. E. Reid, in a letter drafted for him by Elton Miller, new head of the Aerodynamics Division, replied to Lewis that Langley would do the work, but the staff was not optimistic. The split flap, they thought, would probably increase drag, decrease lift, and produce the kind of turbulent wake that accompanies separation. Lewis responded with a Washington Navy Yard report which he believed contradicted the staff predictions; one of the engineers at the lab countered that the trailing edge described in that report was a downward flap only, not the split flap recommended by Wright. When the research was concluded and a report prepared the following year, it confirmed the staff's skepticism. Said Reid in forwarding the report to Lewis, "The results obtained in this investigation are mainly negative and it has been doubted whether the paper is worthy of publication." Once more (as in the preliminary sucking-slot tests) the staff at Langley was recommending suppression of negative results, but in this case Lewis seems to have overridden their objections. Five months after the negative recommendation by Langley, the same report, now edited and retitled, was forwarded for publication as a technical note.[17]

The laboratory was more successful in suppressing the results of another investigation tacked onto research authorization 201. In June 1928, a Langley engineer brought to the attention of George Lewis some Japanese research which concluded that rows of transverse flaps across the upper surface of a wing would prevent the backflow of air along the upper surface at high angles of attack—a precondition of separation—with little effect on drag. Tests seemed warranted. Lewis agreed, and authorized tests under research authorization 201. But again the results were disappointing. Early in 1929, Henry Reid forwarded to Lewis a report that he said was based on "somewhat crude" research equipment. He did not recommend the report for publication, and he did not have the personnel to continue the research. The chief test pilot, however, was more optimistic about the technique, as was Lewis, who told LMAL that he found the results interesting and wanted more research done. But there the record stops. Queried about the Japanese technique in 1935, the laboratory staff could find no memorandum report on its research, or even any record of tests beyond some notes in the chief test pilot's own files. In this one case, at least, the laboratory succeeded in smothering a project it did not want to pursue.[18]

Not until the summer of 1929 did the Langley laboratory forward the first findings under research authorization 201 that the staff judged suitable for publication. On 23 August, H. J. E. Reid forwarded a document by Montgomery Knight and Millard J. Bamber, "Wind Tunnel Tests on Airfoil Boundary Layer Control Using Backward Opening Slot," recommending its publication as a technical note. Two months later it appeared as NACA TN-316. Less than two years after that came the culmination of the work under research authorization 201, Millard J. Bamber's "Wind Tunnel Tests on Airfoil Boundary Layer Control Using a Backward Opening Slot." In forwarding this report to headquarters, H. J. E. Reid recommended its publication as a technical *report*, the top of the NACA line and the intended end product of all research authorizations. Reid specifically noted that "the work covered by this report was done under Research Authorization No. 201 and completes the work to be done under this authorization." The following year the report was published as NACA Report 385. In it, Bamber mentioned the personnel limitations on the investigation and suggested that this research was all the NACA was going to conduct on this topic. Reading the records only to this point might lead to the conclusion that research authorization 201 had run its course.[19]

In fact, however, research authorization 201 was just getting under way. Even as Bamber's report was being edited for publication, another report by another engineer went from Langley to headquarters, carrying a note by Reid that the research was conducted under R.A. 201 and did *not* complete the work to be done under that authorization. And, in the same year, another young engineer at Langley, Hugh B. Freeman, submitted a *preliminary* report on an investigation conducted under research authorization 201, this time on pressure distribution about an airship model, an entirely new departure in NACA boundary-layer research.[20] Langley records do not explain why the laboratory decision was overturned and the research authorization left open. Nor do they suggest why R.A. 201 expanded into an umbrella for work not directly connected with the blowing and suction techniques suggested by Katzmayr and Göttingen, the initial targets of the research. There were other research authorizations active under which boundary-layer investigations could be—and in fact were being—conducted. The most likely explanation is the promise offered in Bamber's final report of actually controlling the boundary layer by suction and blowing, and Lewis' reluctance to abandon the research especially when he held an authorization explicitly requested by one of the armed services. Better, perhaps, to keep the authorization open and use it for targets of opportunity: if a promising new departure in research appeared, it could be pursued within the mandate of this research authorization without going back to the Executive Committee and asking for approval of what might appear in embryo a far-fetched line of research.

Whatever the reasons, research authorization 201 remained open, and under its protective cover all manner of boundary-layer research went on. In 1932, for example, the newly opened NACA tow tank—a model basin intended primarily for experimentation with seaplane hulls—was drawn into a Navy investigation of soaring birds in still air. The scheme, not especially well received at Langley, was to harness seagulls, buzzards, and seahawks to a movable carriage in the NACA tank and pull them along at varying speeds, to measure the lift their wings developed at different attitudes and degrees of extension. Constructing a balance that could measure the results of these tests became a major research project per se, and the Langley staff found itself not only yielding up precious tank time to the enterprise but also becoming immersed in procuring test specimens and designing and supervising construction of the balance.[21]

But these tank tests were merely a distraction and an aberration. The real center of activity on research authorization 201 in the next phase of its long career was to be Hugh B. Freeman, the young engineer who reported late in 1931 on airship research. In a memorandum to the chief of the Langley Aerodynamics Division in April 1932, Freeman argued that boundary-layer control had enormous potential that was being overlooked. His work on airflow around airships had convinced him of this, and he was dismayed to learn that the NACA's only major work on the subject was Bamber's technical report. Freeman considered Carroll's earlier work on the blowing slot in a wing section a step in the right direction, and he outlined a program to continue that research.[22]

On the same day that Freeman formally presented his proposal, H.J.E. Reid wrote to headquarters that key staff members agreed on its possibilities. Recommending approval of the proposed research, Reid noted that "it may be advisable to request an extension of Research Authorization No. 201 . . . to permit work being carried out in the propeller research tunnel. It will be recalled that the above research authorization authorizes work in the atmospheric tunnel." Why this deviation from the original authorization needed new approval, when Lewis had freely approved R.A. 201 work in the variable-density tunnel and the NACA tank (not to mention departing from the type of work originally prescribed), Reid did not say. Perhaps this looked to him like a major new investigation which should bear a reaffirmation of R.A. 201 from the outset. Lewis apparently did not share Reid's view, but told the laboratory to draw up a detailed program; when that reached his hands some three months later, he quickly approved it for inclusion in research authorization 201 with no apparent endorsement by the Executive Committee.[23]

In essence Freeman proposed to investigate lowering the drag on airships by using boundary-layer control to delay transition. This was truly a new departure in the history of R.A. 201.[24] Previous efforts had sought for ways to delay separation and increase the velocity gradient within the boundary layer. Freeman would concentrate on delaying the transition from laminar to turbulent flow. The idea was by no means original with him, but his work on airships and his reading of earlier NACA efforts convinced him that this was a promising line of research and one with which the NACA should be deeply involved. He was right. It would be in this area—though not under this R.A.—that the NACA would make its greatest contribution to boundary-layer control, the laminar-flow airfoil.

While Freeman was occupied with this research, over the long stretch between proposal and publication of results, word of his study was abroad in aeronautical circles. One who heard about it was Clark B. Millikan, a young aeronautical engineer at the California Institute of Technology who would in time become one of America's leading aerodynamical theorists. In 1933 he was assistant to Theodore von Kármán, Ludwig Prandtl's most famous American protegé, and in July of that year he asked the NACA for Freeman's boundary-layer data to use in the work he and von Kármán had been conducting for more than a year. George Lewis asked the Langley lab what Miller (chief of the Aerodynamics Division) thought of the request, and Reid replied for the laboratory "[that] the tests made thus far are of a preliminary nature intended mainly to establish the satisfactory working of the equipment and that the results are not of a nature suitable for release by the Committee."[25] The NACA's long-standing reluctance to share preliminary data with industry, lest they be misinterpreted, was being extended to the scientific community where colleagues customarily shared preliminary results—even negative ones—so long as they advanced the common store of knowledge. This sort of answer, unsatisfactory even to industry, was sure to be doubly unpalatable to scientists.

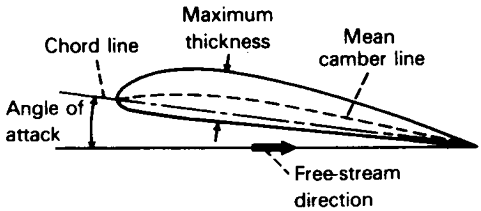
Some few, however, were privy to the NACA's closed work on boundary-layer control. George Lewis showed charts of Freeman's early results in the propeller-research tunnel to Walter Diehl, a Navy captain who was a prolific contributor to NACA technical publications and for years was the Navy's principal working-level contact with the NACA. Diehl was interested. He believed that wing flaps had largely solved the navy's landing problems but takeoff was still a major difficulty. Some of the current planes needed as much as 1000 feet in which to take off, a distance that could only increase with increased speeds. Boundary-layer control offered a possible solution to this problem. Diehl reported that an engineer at one of the leading aircraft manufacturers had suggested cooling engines by a blower fan in the wing; this seemed a good source of pressurized air to be released through forward slots. Diehl recommended tests of the idea.[26]

Freeman replied for the laboratory to Diehl's letter. First he set the captain straight: flaps had not entirely solved landing problems. Lateral control was still a difficulty, especially if the flaps extended the full span of the wing and interfered with the ailerons. But even here, said Freeman, boundary-layer control offered a solution, for it promised a high lift coefficient, elimination of stalling, and a smooth flow conducive to good aileron control at all angles of attack. He reported that data were not yet available on the use of boundary-layer control for improving takeoff, but were expected soon. As to the suggestion by the manufacturing engineer, Freeman treated it with a trace of institutional defensiveness: "The scheme proposed by Mr. Leighton seems entirely practicable. Indeed the idea had been discussed in this office (before we heard of Mr. Leighton's suggestion) as probably the most promising method of boundary-layer control for very large air transports and bombers in which the motors can be placed inside the wing."[27]

Shortly after this exchange, Freeman submitted his first report on the work he had been doing for more than a year and a half. His memorandum, "Some preliminary results of force tests on a thick stub wing on which the boundary layer was removed by suction and pressure," dated 25 January 1934, set forth lift results and promised that results on drag would soon follow. Major conclusions were that boundary-layer control to increase lift was "much more favorable than previous model tests have indicated," that separation could be entirely eliminated, that suction was more efficient than blowing, that the power for suction or blowing could be obtained from a throttled engine or a "windmill of practicable dimensions" (à la Leighton), and that the results should be checked on a full-span wing.[28]

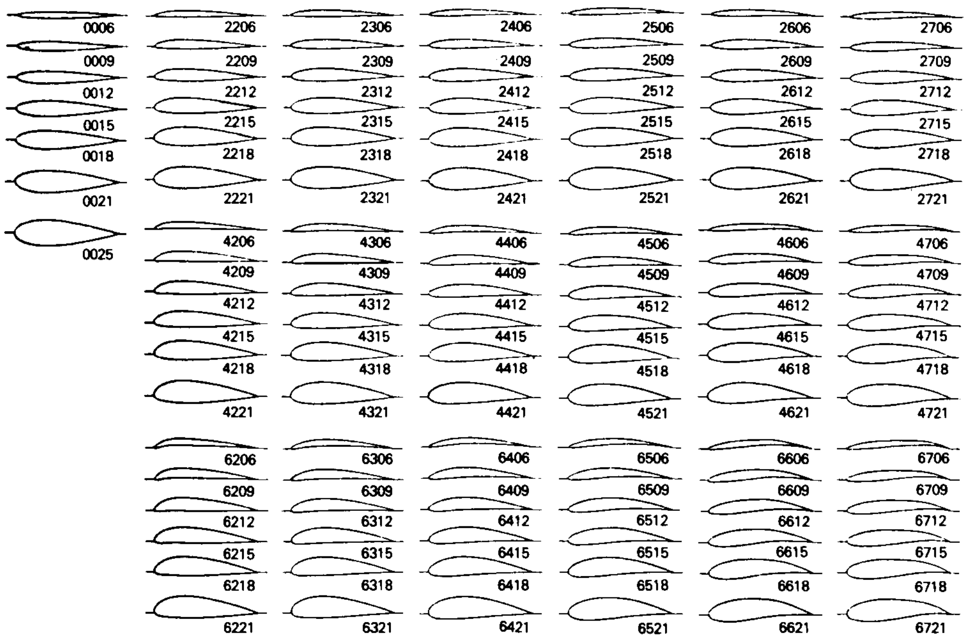
The personnel at Langley were uniformly encouraged by Freeman's report, though they used the cautious, dry language that characterizes engineering correspondence: their comments ranged from "rather interesting" to "most promising." But beneath the restrained wording was clear evidence of excitement. One man suggested sending the report to Lewis, since it revealed why previous tests at the laboratory had been unproductive: the slots had been too small. Another engineer expected that drag would be no problem. Two others had schemes to run the blowers off the propellers; this suggestion led Freeman to alter his plans and run more tests in the propeller research tunnel before proceeding to full-scale inflight tests. Reid sent all this material to Lewis (save Freeman's last reservations) and—in what was becoming laboratory style for this research authorization—recommended getting more complete results before considering the report for publication.[29]

Before answering this correspondence, Lewis discussed it with the staff during one of his frequent visits to the laboratory. The conferees approved Freeman's proposal with one significant alteration: Freeman wanted to run the tests on a symmetrical airfoil, one shaped the same on the top and the bottom. This was not surprising, given his preference for research using theoretically satisfactory shapes, like the body-of-revolution offered by the airship model used in his earlier work. This preference was in tune with current theoretical literature and presumably would give results applicable to all airfoils. Lewis and the Langley staff, however, insisted that Freeman use a NACA 2415 airfoil, a slightly cambered shape from a family of NACA wing sections just then achieving promising results in lift/drag tests at Langley. For several years the NACA had been running exhaustive tests on families of wings whose design components—thickness, camber, taper, etc.—were minutely altered for each succeeding wing to document the change in flight characteristics. This was turning out to be among the most popular and most useful research conducted at Langley, for it gave aircraft designers a whole range of wings from which to choose, as one might select home-furnishing or automobile accessories from a catalogue. Wings thus developed in the laboratory became known by the Committee's name with a number code identifying the features of the wing. The most famous was the "two-thirty" family of wings, introduced in 1935.[30]



(a) Wing cross section.

The camber of an airfoil section is the curvature of the mean line relative to the chord line. (NASA EP-89, 1971, p. 100)



The NACA 4-digit family of airfoil sections: the 00-series are symmetrical, the 24- series slightly cambered. (NASA TR-460, 1933)

Exactly why Lewis and the Langley staff forced Freeman to use the 2415 wing section, the written record does not say. If Lewis wanted merely to ensure mention of a NACA airfoil in Freeman's published results, he could have prescribed any one of an number of Committee-developed symmetrical sections. Lewis may have wanted to spotlight the 24 group of NACA airfoil sections, just then being touted by the Committee as superior to the Clark Y and the R.A.F. 6, two of the most popular airfoils of the time. Whatever the reason, the decision seems to have been purely political, an instance where Lewis allowed his own judgment about the best interests of the Committee to overrule the judgment of the researcher in the laboratory. That Lewis chose to reach this conclusion orally with the Langley staff, rather than to commit his reasons to writing, reinforces this impression.[31]

Like a good soldier, Freeman did as he was told, bringing to the new experiments the same enthusiasm and creativity that had marked his entrance into this field of research. Shortly after selection of the slightly cambered NACA 2415 wing for the tests, Freeman suggested a new slot design to improve the characteristics of such wings at low angles of attack. He proposed a connection between the front bottom of the wing and the rear top. Natural pressures of the airflow at low angles of attack would, according to Freeman, suck air into the wing at the top rear and in turn suck the same air out of the wing at the front bottom, thus moving the boundary layer across the top. Several months later Freeman changed the proposal to put the top intake near midchord instead of at the rear of the wing. In the meantime, he also suggested that the boundary layer might be controlled by adding to the trailing edge of a wing a retractable flap of adjacent tubes, using the Venturi effect to draw air into the tubes and pull it further aft. Freeman thought the latter idea so promising that the government might want to consider a patent.[32]

To Freeman's first suggestion, Lewis gave quick assent for inclusion in research authorization 201. But the notion of the Venturi flap drew a more cautious, more revealing response: First Lewis observed that, at the ninth annual NACA industry conference held recently at Langley, many considered the demonstration of boundary-layer control in the smoke-flow tunnel and the charts illustrating the results of this investigation to be the most interesting exhibition. Furthermore, the Navy Bureau of Aeronautics had expressed interest, so the idea was certainly worth pursuing. But Lewis was reluctant to continue personally evaluating every new departure in the program without more staff work at the laboratory:

> It seems desirable that when suggestions such as Mr. Freeman's are recommended, they be circulated among the various sections of the aerodynamics division. The comments received, together with further suggestions, could be studied by a special committee on boundary-layer control, resulting in a program of investigation that could be recommended by the laboratory.[33]

Perhaps Lewis was just overworked. Perhaps the technicalities of boundary-layer control were simply becoming too much for him. Perhaps the Langley laboratory—whose professional staff had more than doubled since it first proposed boundary-layer research—had simply grown too large to handle on a personal basis. Whatever his reason, Lewis was directing the laboratory to formalize its procedures for administering boundary-layer research, and in the process was giving up to the laboratory some of his autonomy. He approved Freeman's suggestion, just as he had approved all those before it; if the Langley staff was going to speak with one voice on future recommendations, he would be even less likely to override their collective judgment.

Lewis's delegation of authority at this time, his loosening of the reins on the Langley staff, should not be taken out of context. It was no more than an extension of the policy he had followed from the outset of his NACA career. He had always insisted upon the freest discussion and the most open flow of ideas within the Langley staff. He distrusted organizational arrangements that hampered interdisciplinary and interdivision collaboration. When he visited the laboratory, as he did often in the early years, he convened informal staff meetings at which everyone was encouraged to present his views. Lewis fostered, and the laboratory ensured, informal discussions where rank and protocol mattered less than the worth of the ideas. The most junior engineer could corner his division chief in the cafeteria and argue a case over lunch without fear of overstepping bounds. In setting up a special committee on boundary-layer control, Lewis was trying to guarantee the continuation of this kind of interplay and cooperation even if he were unable to personally supervise and participate. By doing so, he was also laying the groundwork for the collaboration that would lead to the laminar-flow airfoil.[34]

Evidence of Lewis's increasing workload and his need to delegate responsibility came the following month when P. E. Hemke of the Case School of Applied Science wrote to Lewis asking for boundary-layer information. He was conducting some wind-tunnel tests of boundary-layer control and had learned of the NACA's work through the last industry-conference report. Could the NACA advise him on the best positioning of slots, the best method for achieving even air flow distribution along every slot, and the best wing thickness? Lewis, instead of forwarding this to Langley lab for a draft reply as he would have done in previous years, let John Victory handle the correspondence.[35]

This subtle shift did not mean that Lewis had relinquished his final say. In fact, Lewis's intervention in Freeman's wind-tunnel program was about to bear fruit. Freeman reported disappointing results in the tests on the NACA 2415 wing, "as was expected with the use of such a low cambered wing section," he added somewhat acidly, in an "I-told-you-so" tone. He recommended that the tests continue on a more highly cambered and tapered wing, apparently believing that, short of the symmetrical wing section he preferred, he would get best results with a section of greater camber than the 2415 preferred by George Lewis. Others in the division agreed, though Eastman Jacobs—one of the most brilliant and influential men ever to work at Langley—thought that "possibly Freeman has been a little hasty in condemning the slightly cambered airfoil." Still, he agreed with Freeman on the need for a more tapered wing, and the two men selected a satisfactory shape. H.J.E. Reid, trying to proceed as he imagined Lewis would wish, reported that the program would proceed with tests on something like the NACA 8318 airfoil unless disapproved by Lewis, and he added that "the future program will be planned to show the value of boundary-layer control in take-off." Silence from Lewis was interpreted as assent.[36]

Keeping the military services happy was not Lewis's only concern; industry too had become interested in boundary-layer control and was increasingly difficult to put off. Eclipse Aviation Company, for example, learned of NACA research on boundary-layer control and wanted to know if it was too early to consider manufacturing a power supply for the blowers to be used in wings for suction or blowing. Freeman thought this might be an excellent chance for the laboratory to get a prototype manufactured free for testing, but more conservative voices at Langley prevailed; Eclipse Aviation was finally told that the requirements were not clear enough for manufacturing.[37]

Of greater concern to Lewis was a request from the Northrup Company, which in early 1935 was having boundary-layer control tests conducted at the California Institute of Technology. Lewis discussed this and other boundary-layer research in the United States with Donald H. Wood when the latter visited headquarters from his post in the Aerodynamics Division at Langley. Would it be possible, Lewis wanted to know, to publish some results of the work already done at Langley and continue the testing on an actual airplane? As Wood made clear when he returned to Langley,[38] airplane tests had been proposed by Freeman more than a year previously when Lewis intervened and insisted on tunnel tests on an NACA airfoil. "It appears now," lamented Wood, "that airplane tests would be very useful in establishing the priority of our investigations but it is a pity that this was not realized a year ago when the tests were suggested here."

This lost opportunity prompted Wood to examine how the boundary-layer research program at Langley had been conducted. He noted that (as had been suggested elsewhere) "the work on the general project has not been pushed sufficiently," a failure he attributed to shortage of personnel and the press of "other projects deemed of equal or greater importance." Less forgivable was the "constant shuffling about of personnel in the drafting room and shops to work on projects of momentary and changing first importance." Compounding these shortcomings in the laboratory was the premature announcement of research programs at the annual industry conferences. "The fact that we announced results of incomplete tests at the last mfg conference," he concluded, "has stimulated interest and the fact that we have published nothing now puts us in an embarassing situation," one that "will continue . . . so long as we continue to give out advance information each year." The only way out of the present dilemma, he believed, was to override Freeman's reticence and get something into print. "I know that Mr. Freeman is somewhat adverse to putting out information on the inconclusive tests so far made," argued Wood, "but I think that under the circumstances it might be well to get out a confidential note on the results obtained to date. This would place us on record and give Northrup a starting point for his tests which I don't think he would misuse."

The chief of the Aerodynamics Division agreed with Wood, though he doubted that design of an airplane wing could begin until tunnel tests were completed. So, while the work proceeded apace, Freeman prepared "Large-Scale Boundary-Layer Control Tests on Two Wings in the N.A.C.A. 20-Foot Wind Tunnel" as a Confidential Memorandum Report.[39] In forwarding this report to headquarters, Reid advised that it had not been edited and was not intended for wide circulation in its present form. Its contents would be included with other material in a future Technical Report.[40]

Outsiders from industry, the services, and academia were not the only ones inquiring after the progress of boundary-layer research at Langley and thereby affecting the course of the research program. For example, Charles H. Helms, a headquarters aeronautical engineer specializing in advanced design studies, patents, and inventions, offered two ideas for boundary-layer control to Lewis, who sent them along to Langley for comment. Helms suggested an endless belt along the upper surface of a wing to keep the boundary layer moving at the speed of the airstream, and he suggested vibration to shake the boundary layer loose. Eastman Jacobs responded with a perfunctory "no comment." Freeman replied that the endless-belt idea, which had been patented in Germany in 1917, was impractical, while the vibration technique was "like attempting to lose one's shadow. No matter how quickly the surface is moved by vibrating it, the air is forced to follow."[41]

This exchange would not have affected research authorization 201 except that it involved Helms actively in the program. Two months after Helms made his suggestions, Lewis asked him to comment on a new idea of Freeman's. Prompted by a private individual's expression of support for the Venturi effect as a means of controlling boundary layer, Freeman dusted off his proposal of the previous year and sent Lewis an expanded version of it for approval as part of research authorization 201. Helms's comment was that Langley should be aiming at reduced profile drag* as the real product of boundary-layer control, not at increased lift as envisioned by Freeman. Said Helms, "If there is anything to boundary layer control, and I think there is, we should be the ones to lead the way, even to the point of actually applying it. I have been of the

*Profile drag is friction drag plus drag due to separation.

opinion for a long time that in this particular phenomenon is the graveyard of all slots, slits, slats, auxiliary air foils, and flaps." [42]

Whatever the virtues of this appraisal, it was sufficiently at odds with the Freeman proposal to place Lewis between conflicting technical recommendations. He sent Helms's comments to Langley for the staff's reaction before approving the Venturi research.[43]

In the meantime, however, Freeman had drafted an entirely new proposal to bring order out of the chaos engulfing boundary-layer research at Langley. Freeman took time to express agreement in principle with Helms while lecturing him on the technical inaccuracies of his analysis.[44] But past deeds seemed unimportant now, for Freeman was caught up in a drive to have his rationalized research program in boundary-layer control approved at both the laboratory and headquarters.

Freeman's proposal went to the chief of the Aerodynamics Division in a memorandum dated 5 August 1935. In it, Freeman noted that most drag on aircraft is skin friction. Boundary-layer phenomena influence skin friction. Two types of boundary layers are known, laminar and turbulent, but little is known of the transition from one to the other. It had been proposed three years earlier to study thick wings, but the sections used were found unsuitable. Then, said Freeman, he had suggested a study of boundary-layer phenomena about an airship hull, which seems to have been a ploy to get around Lewis's insistence on a NACA airfoil and to work with a more theoretically satisfactory shape. This last proposal had even been approved by the Subcommittee on Airships, but was finally dropped because of the "stigma" attached to these craft, or so Freeman guessed. Now he thought it was time for a comprehensive approach along all the most promising lines. He recommended three major areas of boundary-layer research: conventional and very thick wings, effects of surface texture, and effects of surface lubrication—i.e., oils and soaps.

As Lewis had requested the previous year in dealing with proposals, Reid called a conference of the leading aerodynamicists at Langley to evaluate Freeman's new proposal and make a report to headquarters. Besides Wood, Miller, Jacobs, Reid, and Freeman—the men primarily involved in boundary-layer research at Langley—the conferees included Theodore Theodorsen, a theoretician comparable in position (though not in personality) to Max Munk, and Albert E. von Doenhoff, a young engineer on the verge of a major role in boundary-layer research at Langley. The conferees agreed in principle with Freeman's proposal and explicitly endorsed his suggested use of a symmetrical wing, revealing wide opposition at the laboratory to Lewis's insistence on a NACA 2415 airfoil. They did not feel, however, that research on surface texture and lubrication were of primary importance; rather, they recommended more promising avenues of study. Von Doenhoff's proposal for smoke-tunnel tests of boundary layer would be pursued unless it duplicated work at the Massachusetts Institute of Technology or elsewhere, or unless Hugh L. Dryden, head of the National Bureau of Standards's boundary-layer research program, thought it ill advised. Dryden's laboratory had been conducting sophisticated research on measurements of fluid flow about a solid body, some of it under contract to the NACA, and his opinion was highly valued, not just at Langley but also throughout the aeronautical community in the United States and abroad. The conferees further agreed that boundary-layer research should aim at high lift, and that several high-lift devices should be tested in the Variable Density Wind Tunnel. Whereas this plan seemed to contradict Helms's recommendation in his critique of Freeman, it was actually (as Jacobs pointed out) the opposite side of the same medal. As Reid reported Jacobs's thoughts on the subject—perhaps in a conscious effort to appease Helms—he introduced what would become a turning point in boundary-layer research at Langley:

It was agreed that Mr. Jacobs would prepare a memorandum pointing out the possibility of increasing the speed of airplanes by the use of boundary-layer control to obtain high lift, thus enabling the designer to cut down the wing area, increasing the wing loading, which obviously would decrease the total drag.[45]

The memorandum Jacobs turned in six days later may properly be called the result of Freeman's dissatisfaction with the pathlessness of work on research authorization 201, Helms's criticism of the pursuit of lift instead of drag reduction, the independent work Jacobs had been doing under another research authorization, and finally Jacobs's own genius for synthesis and conceptualization. He had found that increased wing loading of a "normal airfoil" produced "surprisingly large" increases in speed. He hypothesized seven reasons for this, some of which he felt had been neglected. The reasons ranged from the transparently logical to the seemingly incongruous. Smaller wings, for example, would clearly result in reduced wing-surface cover weight. But the argument that higher speed would result in fuel-weight savings sounds to the uninitiated like hurrying up to get there before the gas runs out.[46]

Eastman Jacobs, whose suggestion that changes in airfoil shape could be used to control the boundary layer led directly to the low-drag airfoil of World War II. (LaRC)

In addition to the favorable features of increased wing loading, Jacobs saw some unfavorable ones. For example, structural weight increases tended to result from shortening wings while maintaining the cross-sectional proportion. "This may be avoided," suggested Jacobs, "by the use of thicker sections, but the analysis has shown that the change to thicker sections is usually not justifiable owing to their higher drag. In fact one of the most important results of the analysis to date is the tentative conclusion that the sections in common use on cantilever wings are too thick." It was indeed one of the most important conclusions, for from it would flow in time the low-drag airfoil and a radical shift in emphasis in boundary-layer research at Langley.

Jacobs went on to suggest rethinking some of the conventional wisdom about aircraft design in view of the potentials of increased wing loading. Aircraft of higher wing loading required faster landing speeds, but perhaps airfields should be designed for aircraft, not aircraft for airfields. Aircraft design should anticipate high-altitude flying, for the difficulties involved in climbing and descending seem outweighed by the advantages, and other difficulties appeared negligible. If high-altitude flight were the goal, work on turbosuperchargers and more powerful engines would be required first. Jacobs was in fact calling for a major reexamination of the assumptions underlying contemporary aeronautical research. To pursue the promising leads already in hand, he insisted on more than the $300 currently allotted to his work.

Jacobs's memorandum was forwarded to Lewis together with the report of the conference that prompted it. Lewis seems to have been overwhelmed. The laboratory was speaking in several voices, and some were not as clear as he might have wished. He sent the whole corpus back to Langley for yet another conference, this time to reach a consensus on the next step in boundary-layer research. This time Miller, Jacobs, and Reid of the first conference were joined by three different engineers in managerial positions; absent were the junior engineers actively engaged in the program. This more senior group concluded that, while boundary-layer control would produce no great savings in drag at high speed, there just wasn't enough knowledge to justify a conclusion on friction drag. The proper course, therefore, was to proceed beyond the models and wing sections already tested and to experiment with a 15-foot-chord wing in the full-scale wind tunnel. This, they hoped, would give them data on friction drag around zero lift with high Reynolds number: that is, with close correlation to actual flight conditions. Presumably they would thus gain a better idea of the most promising path of research.[47]

Data already available had begun to produce publishable results. For example, young von Doenhoff's report "An Application of the von Karman-Millikan Laminar Boundary-Layer Theory and Comparison with Experiment" reached headquarters for publication as a technical note just before the second committee met at Langley to decide on the future course of boundary-layer research. But the heart of Research Authorization 201—the work being done by Freeman—was still withheld from publication. Even when Edward P. Warner, formerly of the Langley staff and a current member of the NACA itself, asked to use Freeman's confidential memorandum report of the previous year in revising his textbook *Airplane Design—Aerodynamics*, Freeman still balked. Lewis insisted that NACA publish the report in the open literature, as a Technical Note or a Technical Report, before it turned up as a citation in a secondary source, but Langley objected, saying that Freeman's results should not be published until they had been checked in tests for tunnel blocking: i.e., to see if the presence of the model in the wind tunnel created variations in the wind pattern that would undermine the validity of the findings. These tests, said Langley, could not be completed in time to meet Warner's deadline. Warner, one of the most knowledgeable men in the field of aeronautics at the time, was presumably competent to judge the proper use of Freeman's preliminary results; but those results were once more withheld from publication in an attempt to further refine and check them. It turned out in the blocking tests that, though "the presence of a lifting body in the airstream modified the distribution of velocity in the test section, and thereby changed the tunnel calibration obtained with the tunnel empty," the change was less than 3 percent and could be ignored.[48]

After almost ten years, research authorization 201 was becoming a classic example of normal research—the kind most often conducted but too seldom reported. It was in sum a rather pathless excursion through an important field. While everyone attested to the potential of the investigation, no one seemed entirely clear as to where it should go or how it should get there. Instead, different avenues of attack were followed simultaneously. New results led to refinements of the program or new lines of research. Most often these were suggested by the staff at Langley (usually junior members), discussed at laboratory conferences, and referred directly to Lewis for approval by him alone. About halfway through the life of the authorization, the results had been disappointing and the future was cloudy. In June of 1936, Smith J. DeFrance reported on a conference with Freeman and Eastman Jacobs:

> It was the consensus of opinion that to date no definite program has been laid down for the investigation of boundary layer and that such a program should be made. The program should be divided into two parts: (a) study of the control of the boundary layer and (b) the practical application to flight. To date not enough is known about the control of the boundary layer to make recommendations for the practical application; therefore, emphasis should be laid on part (a), the study of control.[49]

Such a conclusion is hard to argue with, and George Lewis did not: he quickly approved it.[50] By the same token, it represents no advance in the state of the art after ten years of work. Surely the laboratory was now trying to look at the forest, but ten years amongst the trees had not done much for the researchers' perspective, and Lewis seems simply to have been rubber-stamping their recommendations.

Even though what Lewis approved was not really a program, new lines of attack did emerge from it. For example, von Doenhoff visited Dryden at the National Bureau of Standards to learn how to measure mean air speeds over a solid surface with a hot-wire anemometer, a technique pioneered by Dryden and his staff. And Jacobs reported in July 1936 the conclusion of another Langley staff conference that "adequate systematic investigation [of the boundary layer] requires the construction of special wind-tunnel equipment like the proposed 2-dimensional flow tunnel." [51] This endorsement added weight to the growing demand for a low-turbulence tunnel and brought closer the research that would finally break the NACA through the boundary-layer research impasse.

Some results began to appear, though in the same old pattern: Freeman's report on "Boundary-Layer-Control Tests of a Tapered Wing in the N.A.C.A. 20-Foot Wind Tunnel," originally planned as a Technical Report, was (according to Reid) "too incomplete and too inconclusive." [52] It was not to be published or released to manufacturers, but distributed only to the armed services as a confidential memorandum report. Von Doenhoff was characteristically more open with results submitted the following year (1937) in "Notes on a Preliminary Investigation of Boundary-Layer Transition along a Flat Plate with Adverse Pressure Gradient." He asked that a copy be forwarded to Dryden for comment, with a view to publication. Dryden recommended its publication as a Technical Report, though he cautioned that part of the discussion should be presented less dogmatically, "to convey the idea of a stimulating speculation rather than that of an established theory" for computing scale effect on maximum lift. Von Doenhoff complied, and the report appeared as a Technical Note three months later.[53]

In spite of von Doenhoff's example, Langley still tended to suppress less-than-final results obtained under research authorization 201. A glaring instance occurred in February 1938, when Clark B. Millikan tried again to obtain some preliminary results. Millikan wrote to Lewis that he had read in the Committee's 23d annual report about Langley's boundary-layer control work and felt that the results would be useful to him and his staff at Cal Tech. Alive to the fact that the NACA results might still be inconclusive, Millikan wanted to use them as a guide to keep from plowing the same ground. "It would be very valuable to us," he told Lewis, "if we could have the benefit of some of your experience before starting our program, so that we need not repeat tests for which you have already found answers." [54]

Even the normally reticent Freeman found this request persuasive, and he recommended that his last two confidential memorandum reports should be released to Millikan. Another engineer objected, however, noting that CMRs were normally released only to manufacturers and he saw no reason "to forget this rule in the present case." And others at Langley agreed with him, even though Millikan had freely provided information about his program in his letter to Lewis and even though the theoretical work of Millikan and von Kármán had been the foundation of von Doenhoff's research on laminar flow. The laboratory's answer to Lewis seems to have completely missed the reasoning behind Millikan's request:

> The Laboratory still feels that both these papers should not have any wider distribution than they have had in the past. This feeling is occasioned by the fact that the choice of wings used in these investigations was such that generally applicable conclusions could not be obtained from the results of the investigations. We have done no further work on this subject of boundary-layer control on the wings.[55]

If the laboratory staffers were still trying to chastise Lewis for insisting on the NACA airfoil for Freeman's original tests instead of the more theoretically satisfactory symmetrical wing, they were cutting off their noses to spite their faces. Millikan was not after final results. To deny him the benefit of their experience was to alienate people who would prove important not only to aeronautics, but to the reputation of the NACA as well.

But these early vagaries of research authorization 201 would soon be overshadowed by a breakthrough that changed irrevocably the course of boundary-layer control research at Langley. In the very month that the laboratory's new low-turbulence wind tunnel went into operation—the tunnel for which Jacobs and von Doenhoff had been arguing for years—Jacobs reported to Reid that the most promising future research would be in an almost entirely unanticipated direction. "We can now conclude definitely," he wrote, "that the most likely form of boundary-layer control to reduce drag is through the use of the flow conditions and pressures ordinarily attainable over the section through changes of the section shape to provide the desired control to maintain laminar flow." [56] It was not to be sucking or blowing, then, as presupposed in research authorization 201, that would most successfully control the boundary layer, but wing shape; furthermore, the greatest advantage would be derived from maintaining laminar flow over as much of the upper wing surface as possible and not (as suggested earlier) from energizing or moving the boundary layer itself. Verification of these revolutionary conclusions was made possible by the low-turbulence tunnel, where Jacobs had reduced drag 30 percent and maintained laminar flow to 75 percent of the chord of the wing behind the leading edge. Much work remained to be done, and he would need a new job order to proceed.

Lewis seems not to have immediately appreciated the importance of this breakthrough at first, for he approved Jacobs's request only on condition that it not interfere with icing research scheduled for July and August in the low-turbulence tunnel.[57] Icing of wings and control surfaces on aircraft was just then one of the most important problems the NACA had to solve for commercial operators and the armed services, and Lewis wanted usable results as soon as possible. This icing research had been a major justification for building the low-turbulence tunnel in the first place, and good politics would require using it for that purpose, at least at the outset. In spite of these limitations, Jacobs found sufficient tunnel time to follow up on the laminar-flow research.

The impact of this discovery on research authorization 201 was swift and dramatic. It seems to have killed off interest in Freeman's work and presaged Freeman's departure from the NACA within a few months. Shortly after Jacobs's discovery was announced, Langley had prepared a new proposal by Freeman to study boundary-layer control on bodies of revolution, but by the end of the year Langley withdrew the proposal on the grounds that "increased knowledge of boundary-layer conditions since this letter was written indicates that the proposed program would hardly be worthwhile." [58]

Publication policy also began to change. Langley was now willing to give wider circulation to Freeman's 1936 report, perhaps in the belief that further research in that area seemed unlikely. At the same time von Doenhoff began publishing in the newer field of laminar-flow research. His first report, "A Method of Rapidly Estimating the Position of the Laminar Separation Point," was sent to headquarters for publication as a Technical Note within three months of Jacobs's memo.[59] Others followed less rapidly, but upon their appearance reversed the procedure used in Freeman's case early in the 1930s. Now, the first results published were on a symmetrical airfoil in a low-turbulence tunnel. Only after those theoretically satisfactory results were printed did the NACA begin issuing data on a family of cambered airfoils, the new laminar-flow or low-drag wings. In this research, von Doenhoff was joined by names new to research authorization 201. By 1942, these experiments had graduated into flight tests, and the first practical application—a low-drag wing on an operational aircraft—was already being used on the P-51 Mustang.[60] The performance of that aircraft in World War II was one of the gems in the NACA diadem, an example ever after of the contribution of NACA research not only to the advance of American aeronautics but also to the winning of World War II.

But then von Doenhoff began following the same course Freeman had taken almost a decade before, recommending changes in the research program. In fact von Doenhoff proposed to study the very problem for which research authorization 201 was opened in the first place: whether blowing or suction could be used to control boundary layers, on the surfaces of wings as well as internally in ducts and passages.[61]

Times, however, had changed. There was a war on and George Lewis was reluctant to approve new proposals as he had during the 1930s. He told Langley that von Doenhoff's suggestion would be referred to the next meeting of the Aerodynamics Committee, but four months went by without any action. H. J. E. Reid finally wrote to Lewis asking about the proposal, advising the director that "the Laboratory has already initiated work on this job pending approval of this project by your office." [62] Apparently Lewis's rubber-stamping of Langley proposals during the 1930s had bred in the laboratory a habit of autonomy that considered approval by Washington a mere bureaucratic routine.

Lewis was working in a new atmosphere, however, and could not accept the old justifications. "It would be desirable," he advised the laboratory, "if the proposed investigation of turbulent boundary layers could be conducted in connection with some specific project having a direct bearing on applications to wings or duct designs in preference to a long-range study such as has been proposed by the laboratory." In essence Lewis was saying there could be no more fundamental research for the duration. All NACA effort must contribute to the war effort; if basic research was authorized, it would have to show promise of practical application to the war. Reid met Lewis's demand with a bromide so general as to be virtually meaningless. In proposing to conduct the work under research authorization 201, he assured Lewis that the research "is of a fundamental character and the results will be applicable to current problems relative to military aircraft both to wing development and to ducting problems as well." Couched in those terms, the research was quickly approved by Lewis, apparently without reference to the Aerodynamics Committee.[63]

Even the reports being generated under research authorization 201 had to be oriented to practical applications. When a report by von Doenhoff and another engineer on "Determination of General Relations for the Behavior of Turbulent Boundary Layers" went to headquarters early in 1943, it was returned with the recommendation of a staff engineer that it be expanded to show practical application. Reid replied that more research was required before the practical applications could be determined, indicating that (at least in this instance) the laboratory continued to do fundamental research even as headquarters was insisting on practical results.[64]

This demand by headquarters for practical results may account for the diminished level of work done under research authorization 201 in the final years of the war. Although work did continue during 1943 and 1944, it was on a comparatively reduced scale, producing in the latter year only one advanced confidential report and one confidential bulletin. A representative of Lockheed Aircraft Corporation who visited Langley in January 1945 was told by the staff that "although we are very interested in boundary layer control we have no new data on the subject." [65]

As World War II drew to a close, Lewis reported from Washington a "revival of interest in boundary layer control as a means of reducing landing speeds." He asked the Langley staff about reissuing some of the old classified reports. A committee at the laboratory had already addressed that question and concluded that Freeman's 1935 report was worth reissuing, but the 1936 report was not. Nor was more enthusiasm shown when Hugh Dryden reported from Europe on the German work in boundary-layer control during the war. The staff at Langley could find nothing new in his report, even though Dryden (surely no novice in the field) found much of interest.[66] With Technical Note 1007 (the reprint of Freeman's 1935 report) published in January 1946, the Langley laboratory closed the book on research authorization 201. The laboratory would do more work on boundary-layer control but not under this research authorization—which, after all, had been opened nearly twenty years earlier to compare the suction method of the Göttingen aerodynamicists with the blowing method of Richard Katzmayr.

Whatever the achievements and shortcomings of research authorization 201, its history provides a classic example of the research process, with implications far beyond the details of how the NACA conducted aeronautical research in the second quarter of the 20th century. Among the many lessons to be learned here, a few are particularly clear and poignant. George Lewis attempted—with diminishing success as time went on—to maintain personal control over the research program at Langley and to channel it in directions of political use to the NACA and immediate practical use to its clients. The Langley staff displayed a continuing reluctance to publish preliminary results or even to share them with knowledgeable colleagues like Clark Millikan and Edward P. Warner. The Langley laboratory maintained an openness to new ideas and suggestions, even from junior staff members, that seemed so extreme at times as to make of RA 201 a rudderless craft with too many hands at the sheets, precisely the problem envisioned by Max Munk when he chastened E. G. Reid at the outset. Eastman Jacobs's discovery of boundary-layer control through modification of airfoil shape illustrates the serendipitous nature of research, and the way in which one line of investigation will often lead to more fruitful conclusions than those anticipated. It also shows how a revolutionary piece of research equipment—in this case, the low-turbulence wind tunnel—can dramatically alter the course of research. Finally, it should be noted that boundary-layer control is still an intriguing and elusive technique that attracts and frustrates aerodynamic researchers even 35 years after the close of research authorization 201. If the research under that authorization left a trail that now appears aimless and confused, it was for that very reason typical of most research into the unknown.

Appendix G
Reports

The NACA produced six series of reports that were "published" in the commonly accepted sense of that term: i.e., issued to the public. Very often the public to which the reports were issued was a limited one—selected members of the military services or the American aircraft industry—but the reports were nevertheless public in the sense of being available to anyone with a demonstrable need to know the information they contained.

Heading the hierarchy was the Technical Report (TR), later called simply the NACA Report. TRs were the most prestigious, the most polished, the most important, and the most widely distributed of all NACA reports. Printed by the Government Printing Office, bound each year with the Committee's Annual Report to Congress, and distributed by subscription to a mailing list of laboratories, libraries, factories, and military installations around the world, the TR was the rock to which the NACA anchored its reputation.

Considered by the Committee to be "lasting contributions to the body of aeronautical knowledge," [1] the NACA Reports generally announced the final results of a research project. Thus they were usually the last of a series of reports, consolidating and summarizing information disseminated in earlier interim reports. The distinguishing mark of the TRs was the thoroughness with which they treated the entire topic, and with which they were edited and checked for content and style. The rarity of mistakes in an NACA report was a quality that aeronautical engineers around the world came to rely upon and value.

Recognizing a need to publicize research that might be incomplete or of insufficient significance to warrant a Technical Report, the NACA instituted in 1920 a second series called Technical Notes (TN). Reproduced within the NACA and distributed to addressees in the aeronautical and related industries, contractors, leading universities, and the larger public libraries, these documents reported on significant portions of NACA research projects, on research sponsored by the NACA in colleges and universities, and on preliminary theoretical work done by the NACA. Often the information in one or more Technical Notes would be combined, analyzed, and refined, and then republished as a Technical Report.

Over the years, the TN came to replace the TR as the most used and most significant NACA report. After World War II, no TRs were actually prepared as Reports. Rather, each year's production of TNs was evaluated annually by a committee at headquarters and those considered most worthy were republished as TRs.

Less formal still than the TN was the Research Memorandum (RM), introduced in 1946 to meet the need for rapid dissemination of defense-related aeronautical information. Reproduced within the NACA and generally restricted by military-security classification, Research Memorandums normally dealt with fragments of research projects. They might advance unproven theories for discussion, or report on a specific piece of military hardware, or present data that had not yet been completely analyzed. Their main function was to disperse information quickly, so the editing, illustrating, and printing were greatly expedited. In the NACA's later years, a Technical Report might take a year or two between first draft and final publication, whereas the Research Memorandum would take only a matter of weeks.

The Research Memorandum replaced six series of reports instituted by the NACA before and during World War II to meet the needs of the services and industry for aeronautical information related to the war effort. All these reports were classified and received only limited circulation. All were designed for rapid dissemination of information.

A fourth type, advance reports, presented results that before the war would have been issued as Technical Notes or Technical Reports. Advance Confidential Reports (ACR) dealt with guarded subjects such as low-drag wings, late-compressibility wings, and jet propulsion; with general investigations of specific military airplanes; or with projects designated confidential by the army or navy. They were sent by registered mail and had to be kept in locked files when not in use. Normally they were issued to the subcommittees concerned, the NACA's laboratories, and the army and navy, as well as representatives of the aeronautical industry who had signed secrecy agreements with the services and were known to have a need for the information.[2] Advance Restricted Reports (ARR) contained results of other investigations having general engineering applications. Distribution was determined in the same way as for ACRs, but secrecy requirements were less severe to permit wider usage among those having a legitimate interest in the information.

Bulletins were short progress reports (usually from one to six pages) on limited phases of long investigations or on results of very brief investigations. Confidential Bulletins (CB) and Restricted Bulletins (RB) dealt with subjects appropriate to ARRs. Bulletins were distributed in the same way as advance reports.

Memorandum Reports (MR), a sixth type, prepared chiefly for the information of one or both of the military services (or occasionally for one particular subcommittee), contained subject matter not of general application but of interest to a limited number of readers, generally on a specific airplane or engine design.[3] Classified versions of these reports were called Confidential Memorandum Reports (CMR) or Restricted Memorandum Reports (RMR).

After World War II, the NACA reviewed its wartime papers and declassified for publication those of continuing interest and significance. Some few were upgraded to RMs, TNs, or even TRs; most were published in a unique series called Wartime Reports (WR) that appeared between 1946 and 1948 and made available to the NACA's clients all the wartime research not still classified.

The NACA published two other series of papers, neither of which reported original research sponsored or conducted by the Committee. Technical Memorandums (TM) reprinted reports and articles from other research laboratories which the Committee felt should have wider dissemination than they had received in their original form. These were often translations of foreign-language reports otherwise unavailable to the American aeronautical community. Finally, between 1926 and 1937, the NACA published a series called Aircraft Circulars (AC). These were reprints, mostly of published articles, containing descriptions and specifications of individual aircraft. These two were often from foreign sources, bringing to the attention of Americans the latest designs from Europe and elsewhere.

The only other significant series was the Contract Reports (CR). These were apparently intended for internal NACA use when work done under contract to the NACA by an outside organization or individual was not deemed suitable for wider publication.

The library at the Langley Research Center holds index cards on a handful of other NACA reports: RIs, CCRs, CIs, and MRRs. These appear negligible, as do the few miscellaneous letters and memoranda that served from time to time as reports.

Table G-1 explains the system used by the NACA to designate its reports.

Table G–1

Numbering System for NACA Publications Series

Series	Symbol	Consecutive?	Based on source?**	Based on year/month/day of issue?	Example
Reports	None	Yes	No	No	Report 1004: 1004th Report issued
Technical Notes	TN	Yes	No	No	TN–2432: 2432nd Technical Note issued
Technical Memorandums	TM	Yes	No	No	TM–1313: 1313th Technical Memorandum issued
Wartime Reports	WR	Yes	Yes	No	WR A–6: 6th Wartime Report based on Ames research; reported earlier to a limited audience and reprinted
Aircraft Circulars	AC	Yes	No	No	AC–150: 150th Aircraft Circular issued
Research Memorandums	RM	No	Yes	Yes	RM–L9K03a: Research Memorandum written by Langley personnel in 1949 and issued November 3, being the second RM released on that date
Advance Confidential Reports	ACR	No	Yes, after March, 1944*.	Yes, after April, 1943*.	ACR–E4D19: Advance Confidential Report written by Lewis personnel in 1944 and issued April 19
Advance Restricted Reports	ARR	No	Yes, after March, 1944*.	Yes, after April, 1943*.	ARR–L4K22b: Advance Restricted Report written by Langley personnel in 1944 and issued November 22, being the third ARR issued on that date

Table G-1—Continued

Series	Symbol	Consecutive?	Based on source?**	Based on year/ month/day of issue?	Example
Confidential Bulletins	CB	No	Yes, after March, 1944*.	Yes, after April, 1944*.	CB-E5J11: Confidential Bulletin written by Lewis personnel in 1945 and issued October 11
Restricted Bulletins	RB	No	Yes, after March, 1944*.	Yes, after April, 1943*.	RB-E6D22: Restricted Bulletin written by Lewis personnel in 1946 and issued April 22
Memorandum Reports	MR	No	Yes, after October, 1944*.	Yes, after October, 1944*.	MR-A4L12: Memorandum Report written by Ames personnel in 1944 and issued December 12

*Symbol and date only, prior to date mentioned
**A, Ames; E, Lewis; L, Langley
#5: 1945; 50: 1950; 6: 1946; 51: 1951; 7: 1947; 52: 1952; 8: 1948; 53: 1953; 9: 1949; 54: 1959; 55: 1955; 56: 1956; 57: 1957; 58: 1958.
##A, January; B, February; C, March; D, April; E, May; F, June; G, July; H, August; I, September; J, October; K, November; L, December.
###01; 02; 03 . . . etc. to 31, followed by a, 2nd document issued that date, b, 3rd document issued that date.

In the NACA's early years before the Langley laboratory was in full operation, most of its reports were prepared outside the Committee, usually by academics under contract to the NACA. From the 1920s on, most NACA reports were prepared by the Committee's staff, the major exception being those prepared under contract for the Committee throughout its history by the National Bureau of Standards. Unsolicited reports contributed from outside the NACA received consideration for publication, but most were rejected as being incorrect, trivial, inappropriate for the NACA, or not new.[4]

Lee M. Griffith set out the criteria for an ideal NACA report in a 4 September 1918 letter to the Executive Committee (see Appendix H). He recommended that all NACA reports have clear applications, logical discussion, concise summation, a description of the research equipment employed, and a standard style. George Lewis objected to including the description of apparatus, and not until the Committee's last ten years did much information of this type appear in the reports. Griffith's other recommendations were followed more or less consistently throughout the NACA's history.

A characteristic feature of NACA reports is the thoroughness with which they were reviewed and edited, a process that made the final reports late and reliable. In 1922, reports forwarded to headquarters from Langley were reviewed by one or two critics, presented with comments to the Publications Committee, prepared for publication, presented to the appropriate technical subcommittee, and presented at last to the Executive Committee. Only when the report had been approved at each of these stages was it cleared for publication.[5]

Although the procedure was streamlined in later years, by then the review and editing by the staff at the laboratories and at headquarters had grown more complicated. An excerpt from the NACA "Style Manual for Engineering Authors" (as amended in 1932) shows how cautious and time-consuming the review process could be.

> The decision concerning the type (technical report or technical note) of the final paper to be presented is usually made when the job order is authorized. The outline should carry this information. When the copies of the rough draft are forwarded to Washington the letter of transmittal carries the recommendation of the division chief about its form and only in exceptional cases is the recommendation not adopted.
>
> **Revision of outline:**
>
> The outline is then submitted to the section head and the division chief for approval.
>
> **Preparation of the rough draft:**
>
> From the revised outline the author prepares the first draft of the paper. If the draft is well arranged and carefully written, the final report should not differ essentially from it. The author should have the report in the exact form in which he desires to have it printed before he presents it to the section head.
>
> **Revision of the rough draft:**
>
> The section head reads the rough draft and returns it to the author with his comments. The paper is revised until it is satisfactory to both the section head and the author. Five copies of the paper are then typed.
>
> **Criticism by division chief:**
>
> The section head then forwards one copy of the typed report to the division chief, who may note his corrections directly on the paper (author's copy).
>
> **Editing for English:**
>
> The report is sent to the English critic for correction of grammatical and typographical errors, and for noting haziness of composition and faulty arrangement of topics.
>
> **Correction by the author:**
>
> The author, after conferring about debatable points, incorporates the changes proposed by the division chief and the English critic. He forwards to the stenographic section the final corrected copy of the text and five copies of all illustrative material.

Typing:

The stenographic section corrects the remaining four copies by the author's copy, binds all copies with a set of illustrations, and forwards them to the division chief.

Editing for technical context:

The division chief appoints an editorial committee of five, including the author, from the technical staff and forwards to each member a copy of the report with Form L.F. 103. The group meets under the guidance of a chairman and suggests necessary changes in the interest of technical clarity and soundness.

Final revision:

The author corrects his copy lightly and legibly in pencil. He forwards it to the section head, the chairman of the editorial committee, and the division chief for approval. He then returns to the stenographic section the corrected copy, the four uncorrected copies, and the originals of the curves and sketches in their final form. From the corrected author's copy of a report a stencil is cut and twelve copies mimeographed. The stenographic section obtains from the photographic section any extra photographs and from the drafting room the extra blueprints. The copies are then bound.

Transmittal to Washington:

Two copies are retained at the laboratory, one for the section files and one for the office files. For a technical report, ten copies are sent to Washington; for a technical note, three copies. In Washington a technical report goes through the following stages:

a. It is read by one or more critics.
b. It is presented to the Publications Committee.
c. The drawings are prepared for the printer.
d. Its publication is authorized by the Executive Committee.
e. A copy is marked for the printer.

In later years, the review at headquarters could be even more severe. In 1950, for example, staff members at headquarters were "required to check all references and correct the citations before the report is approved for release." [6]

The accuracy and reliability of NACA reports were among their chief virtues, their tardiness in appearing their principal flaw. The tardiness was compounded by the Committee's policy of allowing no publication of research results before they appeared first in a NACA report. Among criticisms of NACA reports over the years included the Committee's reluctance to publish negative results, a tendency to report direct research results without adequate analysis or conclusions, and, oppositely, a tendency to publish faired curves without the data points on which they were based.[7] These criticisms notwithstanding, NACA reports enjoyed a high reputation in aeronautical circles and were much sought after. Many are still being used.

During its 43 years, the NACA produced more than 16,000 reports, averaging slightly more than one a day. Tables G–2 and G–3 show the numbers of reports in each category.

Table G–2

Principal Published Series

	Number of reports	Number of bound volumes
TR	1,392	43
TN	4,410	257
RM	6,163	599
TM	1,441	73
WR	1,274	78
AC	209	7

Table G–3
World War II and Miscellaneous Series

	Later published in a bound series	Never published in a bound series	Total
ACR	223	39	262
ARR	346	67	413
CB	47	19	66
RB	114	40	154
MR	322	429	751
CMR	114	866	980
CR	212	338	550
RI	0	7	7
CCR	0	2	2
CI	0	3	3
MRR	0	8	8
		1,818	

Total published in bound volumes (from Table G–2)	14,889
Total never published in bound volumes	1,818
Total	16,697

The expected interest in, and clearance to see, each of the Committee's reports dictated how many copies were printed. Thousands of copies of Technical Reports were printed and distributed around the world. In contrast, the Committee made only 10 copies of each Confidential Memorandum Report and Restricted Memorandum Report and these were distributed only within the NACA and the armed services.

Like the Committee itself, the NACA reports were intended to advance American aeronautics. As George Lewis advised John J. Ide in 1929, "Technical Notes, Technical Memorandums, and Aircraft Circulars of the Committee [were] issued only for the information of American manufacturers and aeronautical engineers." [8]

Any automatic distribution overseas of these reports was intended as a courtesy extended to friends and allies in expectation of receiving similar information in return. For example, the Committee regularly sent its reports to the British Aeronautical Research Committee, whose reports were received by the NACA in return. Furthermore, Ide normally got a modest number of reports to distribute at his discretion where he thought they would elicit valuable information in return. None of this, of course, prevented foreign governments from seeing and copying these reports in aeronautical libraries across the United States and in select locations around the world. It merely denied them the free receipt of the reports enjoyed by American firms and engineers, either through automatic distribution or on request.

The total number of copies of reports distributed each year increased rapidly in the years before World War II. In 1923, for example, the NACA sent out 36,870 reports, whereas in 1930 it distributed 112,010. World War II, however, put the Committee's reports under two new restrictions which prevailed for the rest of its years. First, the NACA increased its stock of proprietary information as it did more and more cleanup and refinement of prototype aircraft and engines. Publication of the results of this work would amount to giving away trade secrets. The NACA therefore had to limit distribution of such reports to the armed services and to the manufacturer of origin. After World War II, the NACA tried to return to fundamental research whose results would apply to all aeronautics, but it never entirely freed itself from involvement with proprietary information.

World War II also brought the NACA into increased contact with classified information. Here the Committee deferred almost entirely to the military services: NACA reports on military aircraft and equipment were classified and distributed according to military criteria. During the war, the services themselves distributed NACA Confidential Memorandum Reports and Restricted Memorandum Reports; all others were distributed by the NACA according to military guidelines. If anything, it appears that the Committee was even more restrictive than the services in classifying and distributing its reports. For example, until May of 1941, the Committee made all its advance reports *confidential,* when the less severe *restricted* classification would have sufficed for many. When industry complained, the NACA created the separate series Advance Confidential Reports and Advance Restricted Reports.[9]

After World War II, the NACA tried to declassify and publish the results of its wartime research in the Wartime Reports series. Some of this information, however, remained classified for many years after the war, and new research by the Committee was also classified or proprietary. Some TNs and RMs published after World War II were classified; some were not. Distribution depended on content and was determined case by case. The Committee began a regular program of declassifying and redistributing its reports.

Table G–4 shows distribution of NACA reports during the years for which information is available. (Figures for the blank years no doubt exist somewhere in the NACA files, but they did not appear in the course of research for this study and they defied repeated attempts to ferret them out.) Note the cutback brought on by the Depression, the great increase during World War II, the precipitous decline in the NACA's later years, and the shifting ratio of reports distributed automatically to those distributed by request.

Table G-4
Distribution of NACA Reports, by Year (estimated)*

	Total	Requested	Automatic distribution
1915	350*		
1916	1,500*		
1917	3,000*		
1918	6,000*		
1919	10,000*		
1920	23,317		
1921	31,659	15,244	16,406
1922	32,366	13,860	18,406
1923	37,261	18,905	18,356
1924	37,141	15,469	21,672
1925	35,844	18,939	16,945
1926	39,207	21,029	18,178
1927	55,636	31,758	23,878
1928	70,665	49,540	21,123
1929	104,076	77,729	26,347
1930	112,010	76,262	35,748
1931	112,687	72,080	40,607
1932	94,494	54,022	40,472
1933	83,991	50,017	33,974
1934	82,114	51,147	30,967
1935	86,718	48,513	38,205
1936	91,712	52,395	39,317
1937	91,838	50,771	41,607
1938	99,933	56,822	43,111
1939			
1940	101,735	64,188	37,547
1941	87,077	56,515	30,562
1942	98,392	52,477	45,945
1943	126,989	63,066	63,923
1944	109,042	42,776	66,266
1945	122,771	51,126	71,645
1946	189,618	58,980	130,638
1947	38,469		
1948	41,890	10,686	31,204
1949			
1950	28,554	7,887	20,667
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			

In 1950 the NACA published an *Index of NACA Technical Publications, 1915–1949,* which was supplemented in 1951, 1953, and annually thereafter through 1960. Each supplemental volume listed the unclassified NACA technical reports issued since the last index and any reports from previous years declassified during the interval. Taken together, the indexes constitute a guide to all NACA technical reports except for those not declassified until after 1960.

Table G-5 lists subject headings in the 1957 *Index.* Except for category "1.4 Internal Aerodynamics," it was identical to the classification system used for all the other indexes. Table G-6 provides the conversion scheme for correlating 1.4 in the 1915–1949 index with that category in subsequent volumes. Some other subjects were added in later years, but the numbering did not change.

All NACA reports were categorized under one or more of the subject headings. The multiple listing makes it difficult to get from these indexes a total count of NACA reports, which numbered approximately 16,000 over the years; the indexes contain more than 40,000 entries, meaning that each report was indexed under an average of 2.5 different headings.

In spite of this multiple listing, the indexes allow the researcher to draw a few conclusions. Some subjects, for example, have hardly any entries: only 3 for diameter as a design variable of the aerodynamics of propellers (1.5.2.10)—all of these in the late 1940s—and only 1 entry each for control of pulse-jet engines (3.2.5) and for standard atmosphere (6.1.1). In contrast, there are 346 entries for turbojet engines (3.1.3), 960 for mach-number effects (1.2.2.6), and 1009 for longitudinal static stability (1.8.1.1.1).[10]

Clearly there were great differences in the amount of work the NACA did in the various branches of aeronautics. Table G-5 suggests how numerous and complex those fields were. Table G-7 shows the distribution of the NACA's reports—and, by inference, of its research—among the twelve principal subject areas. The figures are percentages of the total number of entries in the indexes, both for the entire history of the Committee and for each year. Aerodynamics, which accounted for 59 percent of all entries in the indexes, accounted for 17 percent of the 1916 entries and 68 percent of the 1949 entries. Figures for individual years reflect the year in which a report was first published.

Table G–5
Subject Headings in 1957 Index of NACA Technical Publications

Number	Subject-Heading
1	AERODYNAMICS
1.1	Fundamental Aerodynamics
1.1.1	Incompressible Flow
1.1.2	Compressible Flow
1.1.2.1	Subsonic Flow
1.1.2.2	Mixed Flow
1.1.2.3	Supersonic Flow
1.1.3	Viscous Flow
1.1.3.1	Laminar Flow
1.1.3.2	Turbulent Flow
1.1.3.3	Jet Mixing
1.1.4	Aerodynamics With Heat
1.1.4.1	Heating
1.1.4.2	Heat Transfer
1.1.4.3	Additions of Heat
1.1.5	Flow of Rarefied Gases
1.1.5.1	Slip Flow
1.1.5.2	Free Molecule Flow
1.1.6	Time-Dependent Flow
1.2	Wings
1.2.1	Wing Sections
1.2.1.1	Section Theory
1.2.1.2	Section Variables
1.2.1.2.1	Camber
1.2.1.2.2	Thickness
1.2.1.2.3	Thickness Distribution
1.2.1.2.4	Inlets and Exits
1.2.1.2.5	Surface Conditions
1.2.1.3	Designated Profiles
1.2.1.4	High-Lift Devices
1.2.1.4.1	Plain Flaps
1.2.1.4.2	Split Flaps
1.2.1.4.3	Slotted Flaps
1.2.1.4.4	Leading-Edge Flaps
1.2.1.4.5	Slots and Slats
1.2.1.5	Controls
1.2.1.5.1	Flap Type
1.2.1.5.2	Spoilers
1.2.1.6	Boundary Layer
1.2.1.6.1	Characteristics
1.2.1.6.2	Control
1.2.1.7	Reynolds-Number Effects
1.2.1.8	Mach-Number Effects
1.2.1.9	Wake
1.2.2	Complete Wings
1.2.2.1	Wing Theory
1.2.2.2	Wing Variables
1.2.2.2.1	Profiles
1.2.2.2.2	Aspect Ratio
1.2.2.2.3	Sweep
1.2.2.2.4	Taper and Twist
1.2.2.2.5	Inlets and Exits
1.2.2.2.6	Surface Conditions
1.2.2.2.7	Dihedral
1.2.2.3	High-Lift Devices
1.2.2.3.1	Trailing-Edge Flaps
1.2.2.3.2	Slots and Slats
1.2.2.3.3	Leading-Edge Flaps
1.2.2.4	Controls
1.2.2.4.1	Flap Type
1.2.2.4.2	Spoilers
1.2.2.4.3	All-Movable
1.2.2.5	Reynolds-Number Effects
1.2.2.6	Mach-Number Effects
1.2.2.7	Wake
1.2.2.8	Boundary Layer
1.2.2.8.1	Characteristics
1.2.2.8.2	Control
1.3	Bodies
1.3.1	Theory
1.3.2	Shape Variables
1.3.2.1	Fineness Ratio
1.3.2.2	Cross Section
1.3.2.3	Thickness Distribution
1.3.2.4	Surface Conditions
1.3.2.5	Protuberances
1.3.3	Canopies
1.3.4	Ducted Bodies
1.3.4.1	Nose Shape
1.3.4.2	Tail Shape
1.3.4.3	Side Inlets
1.3.4.4	Side Exits
1.3.5	Hulls
1.4	Internal Aerodynamics
1.4.1	Air Inlets
1.4.1.1	Nose, Central
1.4.1.1.1	Propeller-Spinner-Cowl Combinations
1.4.1.1.2	Subsonic
1.4.1.1.3	Supersonic
1.4.1.2	Nose, Annular
1.4.1.3	Wing Leading Edge
1.4.1.4	Side
1.4.1.4.1	Scoops
1.4.1.4.2	Submerged
1.4.2	Ducts
1.4.2.1	Diffusers
1.4.2.1.1	Subsonic
1.4.2.1.2	Supersonic
1.4.2.2	Nozzles
1.4.2.3	Pipes
1.4.2.4	Bends
1.4.3	Exits
1.4.4	Jet Pumps and Thrust Augmentors
1.4.5	Cascades

Number	Subject-Heading
1.4.5.1	Theory
1.4.5.2	Experiment
1.4.6	Fans
1.4.7	Boundary Layer
1.4.7.1	Characteristics
1.4.7.2	Control
1.5	Propellers
1.5.1	Theory
1.5.2	Design Variables
1.5.2.1	Blade Sections
1.5.2.2	Solidity
1.5.2.3	Pitch Distribution
1.5.2.4	Blade Plan Forms
1.5.2.5	Mach-Number Effects
1.5.2.6	Pusher
1.5.2.7	Dual Rotation
1.5.2.8	Interference of Bodies
1.5.2.9	Pitch and Yaw
1.5.2.10	Diameter
1.5.3	Designated Types
1.5.4	Slipstream
1.5.5	Selection Charts
1.5.6	Operating Conditions
1.5.7	Propeller-Spinner-Cowl Combinations
1.6	Rotating Wings
1.6.1	Theory
1.6.2	Experimental Studies
1.6.2.1	Power-Driven
1.6.2.2	Autorotating
1.7	Aircraft
1.7.1	Airplanes
1.7.1.1	Components in Combination
1.7.1.1.1	Wing-Fuselage
1.7.1.1.2	Wing-Nacelle
1.7.1.1.3	Tail-Wing and Fuselage
1.7.1.1.4	Propeller and Jet Interference
1.7.1.1.5	Stores
1.7.1.1.6	Jet Interference
1.7.1.2	Specific Airplanes
1.7.1.3	Performance
1.7.2	Missiles
1.7.2.1	Components in Combination
1.7.2.1.1	Wing-Body
1.7.2.1.2	Tail-Body
1.7.2.1.3	Jet Interference
1.7.2.1.4	Wing-Tail-Body
1.7.2.2	Specific Missiles
1.7.3	Rotating-Wing Aircraft
1.7.3.1	Autogiros
1.7.3.2	Helicopters
1.7.4	Seaplanes
1.7.4.1	General Studies
1.7.4.2	Specific Types

Number	Subject-Heading
1.7.5	Airships
1.7.6	Biplanes and Triplanes
1.8	Stability and Control
1.8.1	Stability
1.8.1.1	Static
1.8.1.1.1	Longitudinal
1.8.1.1.2	Lateral
1.8.1.1.3	Directional
1.8.1.2	Dynamic
1.8.1.2.1	Longitudinal
1.8.1.2.2	Lateral and Directional
1.8.1.2.3	Damping Derivatives
1.8.2	Control
1.8.2.1	Longitudinal
1.8.2.2	Lateral
1.8.2.3	Directional
1.8.2.4	Air Brakes
1.8.2.5	Hinge Moments
1.8.2.6	Automatic
1.8.2.7	Jet Reaction
1.8.3	Spinning
1.8.4	Stalling
1.8.5	Flying Qualities
1.8.6	Mass and Gyroscopic Problems
1.8.7	Tumbling
1.8.8	Automatic Stabilization
1.8.9	Tracking
1.9	Aeroelasticity
1.10	Parachutes
2	HYDRODYNAMICS
2.1	Theory
2.2	General Arrangement Studies
2.3	Seaplane Hull Variables
2.3.1	Length-Beam Ratio
2.3.2	Dead Rise
2.3.3	Steps
2.3.4	Afterbody Shape
2.3.5	Forebody Shape
2.3.6	Chines
2.4	Specific Seaplanes and Hulls
2.5	Lateral Stabilizers
2.5.1	Wing-Tip Float
2.6	Planing Surfaces
2.7	Hydrofoils
2.8	Surface Craft
2.9	Ditching Characteristics
2.10	Stability and Control
2.10.1	Longitudinal
2.10.2	Lateral
2.10.3	Directional
3	PROPULSION
3.1	Complete Systems
3.1.1	Reciprocating Engines
3.1.1.1	Spark-Ignition Engines
3.1.1.2	Compression-Ignition (Diesel) Engines

Number	Subject-Heading
3.1.2	Reciprocating Engines Turbines
3.1.2.1	Turbosupercharged Engines
3.1.2.2	Compound Engines
3.1.2.3	Gas Generator—Turbine Engines
3.1.3	Turbojet Engines
3.1.4	Turbo-Propeller Engines
3.1.5	Ducted Propeller Engines
3.1.6	Pulse-Jet Engines
3.1.7	Ram-Jet Engines
3.1.8	Rocket Engines
3.1.9	Jet-Driven Rotors
3.1.10	Nuclear Energy Systems
3.1.11	Miscellaneous Engines
3.1.12	Comparison of Engine Types
3.2	Control of Engines
3.2.1	Charging and Control of Reciprocating Engines
3.2.1.1	Spark-Ignition Engines
3.2.1.2	Compression-Ignition Engines
3.2.1.3	Compound Engines
3.2.2	Control of Turbojet Engines
3.2.3	Control of Turbine-Ram-Jet Engines
3.2.4	Control of Turbine-Propeller Engines
3.2.5	Control of Pulse-Jet Engines
3.2.6	Control of Ram-Jet Engines
3.2.7	Control of Rocket Engines
3.2.8	Control of Gas Generator Engines
3.3	Auxiliary Booster Systems
3.3.1	Reciprocating Engines
3.3.2	Gas Turbines
3.3.2.1	Liquid Injection
3.3.2.2	Afterburning
3.3.2.3	Bleedoff
3.3.3	Rocket Assist
3.4	Fuels
3.4.1	Preparation
3.4.2	Physical and Chemical Properties
3.4.3	Relation to Engine Performance
3.4.3.1	Reciprocating Engines
3.4.3.1.1	Spark-Ignition
3.4.3.1.2	Compression-Ignition (Diesel)
3.4.3.2	Turbine Engines, Ram Jets, Pulse Jets
3.4.3.3	Rockets (Includes Fuel and Oxidant)
3.5	Combustion and Combustors
3.5.1	General Combustion Research
3.5.1.1	Laminar-Flow Combustion

Number	Subject-Heading
3.5.1.2	Turbulent-Flow Combustion
3.5.1.3	Detonation
3.5.1.4	Effects of Fuel Atomization
3.5.1.5	Reaction Mechanisms
3.5.1.6	Ignition of Gases
3.5.2	Effect of Engine Operating Condi- tions and Combustion-Chamber Geometry
3.5.2.1	Reciprocating Engines
3.5.2.1.1	Spark-Ignition Engines
3.5.2.1.2	Compression-Ignition (Diesel) Engines
3.5.2.2	Turbine Engines
3.5.2.3	Ram-Jet Engines
3.5.2.4	Pulse-Jet Engines
3.5.2.5	Rocket Engines
3.6	Compression and Compressors
3.6.1	Flow Theory and Experiment
3.6.1.1	Axial Flow
3.6.1.2	Radial Flow
3.6.1.3	Mixed Flow
3.6.1.4	Positive Displacement
3.6.2	Stress and Vibration
3.6.3	Matching
3.7	Turbines
3.7.1	Flow Theory and Experiment
3.7.1.1	Axial Flow
3.7.1.2	Radial Flow
3.7.1.3	Mixed Flow
3.7.2	Cooling
3.7.3	Stress and Vibration
3.7.4	Matching
3.8	Friction and Lubrication
3.8.1	Theory and Experiment
3.8.1.1	Hydrodynamic Theory
3.8.1.2	Chemistry of Lubrication
3.8.1.3	Surface Conditions
3.8.2	Sliding Contact Surfaces
3.8.2.1	Sleeve Bearings
3.8.2.2	Cylinder and Piston Mechanisms
3.8.2.3	Slipper Plate
3.8.2.4	Kingsbury and Mitchell Bearings
3.8.3	Rolling Contact Surfaces
3.8.3.1	Antifriction Bearings
3.8.4	Sliding and Rolling Contact Surfaces
3.8.4.1	Gears
3.8.5	Lubricants
3.9	Heat Transfer
3.9.1	Theory and Experiment
3.9.1.1	Cascades
3.9.2	Heat Exchangers
3.9.2.1	Radiators
3.9.2.2	Intercoolers

Number	Subject-Heading
3.9.2.3	Aftercoolers
3.9.2.4	Regenerators
3.9.2.5	Oil Coolers
3.10	Cooling of Engines
3.10.1	Reciprocating Engines
3.10.1.1	Liquid-Cooled
3.10.1.2	Air-Cooled
3.10.2	Gas-Turbine Systems
3.10.3	Ram Jets
3.10.4	Pulse Jets
3.10.5	Rockets
3.11	Properties of Gases
3.11.1	Kinetic
3.11.2	Thermodynamic
3.12	Accessories and Accessory Functions
3.12.1	Fuel Systems
3.12.1.1	Spark-Ignition Engines
3.12.1.2	Compression-Ignition Engines
3.12.1.3	Compound Engines
3.12.1.4	Turbojet Engines
3.12.1.5	Turbine-Propeller Engine
3.12.1.6	Pulse-Jet Engines
3.12.1.7	Ram-Jet Engines
3.12.1.8	Rocket Engines
3.12.1.8.1	Turbopump
3.12.2	Ignition Systems
3.12.3	Starting Systems
3.12.4	Lubrication Systems
3.12.5	Cooling Systems
3.13	Vibration and Flutter
4	AIRCRAFT LOADS AND CONSTRUCTION
4.1	Loads
4.1.1	Aerodynamic
4.1.1.1	Wings
4.1.1.1.1	Steady Loads
4.1.1.1.2	Maneuvering
4.1.1.1.3	Gust Loads
4.1.1.1.4	Buffeting Loads
4.1.1.2	Tail
4.1.1.2.1	Steady Loads
4.1.1.2.2	Maneuvering
4.1.1.2.3	Buffeting and Gust
4.1.1.3	Bodies
4.1.1.4	Rotating Wings
4.1.1.5	Aeroelasticity
4.1.2	Landing
4.1.2.1	Impact
4.1.2.1.1	Land
4.1.2.1.2	Water
4.1.2.2	Round-Run
4.1.2.2.1	Land
4.1.2.2.2	Water
4.1.2.3	Prelanding Conditions
4.2	Vibration and Flutter
4.2.1	Wings and Ailerons
4.2.2	Tails
4.2.2.1	Elevators and Rudders
4.2.2.2	Tabs
4.2.3	Bodies
4.2.4	Propeller, Fans, and Compressors
4.2.5	Rotating-Wing Aircraft
4.2.6	Panels and Surface Coverings
4.3	Structures
4.3.1	Columns
4.3.1.1	Tubular
4.3.1.2	Beams
4.3.1.3	Sections
4.3.2	Frames, Gridworks, and Trusses
4.3.3	Plates
4.3.3.1	Flat
4.3.3.1.1	Unstiffened
4.3.3.1.2	Stiffened
4.3.3.2	Curved
4.3.3.2.1	Unstiffened
4.3.3.2.2	Stiffened
4.3.4	Beams
4.3.4.1	Box
4.3.4.2	Diagonal Tension
4.3.5	Shells
4.3.5.1	Cylinders
4.3.5.1.1	Circular
4.3.5.1.2	Elliptical
4.3.5.2	Boxes
4.3.6	Connections
4.3.6.1	Bolted
4.3.6.2	Riveted
4.3.6.3	Welded
4.3.6.4	Bonded
4.3.7	Loads and Stresses
4.3.7.1	Tension
4.3.7.2	Compression
4.3.7.3	Bending
4.3.7.4	Torsion
4.3.7.5	Shear
4.3.7.6	Concentrated
4.3.7.7	Dynamic
4.3.7.7.1	Repeated
4.3.7.7.2	Transient
4.3.7.8	Normal Pressures
4.3.8	Weight Analysis
5	MATERIALS
5.1	Types
5.1.1	Aluminum
5.1.2	Magnesium
5.1.3	Steels
5.1.4	Heat-Resisting Alloys
5.1.5	Ceramics
5.1.6	Plastics
5.1.7	Woods
5.1.8	Adhesives

Number	Subject-Heading
5.1.9	Protective Coatings
5.1.10	Fabrics
5.1.11	Sandwich and Laminates
5.1.12	Ceramals
5.1.13	Titanium
5.2	Properties
5.2.1	Tensile
5.2.2	Compressive
5.2.3	Creep
5.2.4	Stress-Rupture
5.2.5	Fatigue
5.2.6	Shear
5.2.7	Flexural
5.2.8	Corrosion Resistance
5.2.9	Structure
5.2.10	Effects of Nuclear Radiation
5.2.11	Thermal
5.2.12	Multiaxial Stress
5.2.13	Plasticity
5.3	Operating Stresses and Conditions
5.3.1	Airframe
5.3.2	Propulsion System
6	METEOROLOGY
6.1	Atmosphere
6.1.1	Standard Atmosphere
6.1.2	Gusts
6.1.2.1	Structure
6.1.2.2	Frequency
6.1.2.3	Turbulence
6.1.2.4	Alleviation
6.1.3	Electricity
6.2	Ice Formation
7	OPERATING PROBLEMS
7.1	Safety
7.1.1	Pilot-Escape Techniques
7.2	Navigation
7.3	Ice Prevention and Removal
7.3.1	Engine Induction Systems
7.3.2	Propellers

Number	Subject-Heading
7.3.3	Wings and Tails
7.3.4	Windshields
7.3.5	Miscellaneous Accessories
7.3.6	Propulsion Systems
7.4	Noise
7.5	Heating and Ventilating
7.6	Lightning Hazards
7.7	Piloting Techniques
7.8	Physiological
7.9	Fire Hazards
7.10	General
8	INSTRUMENTS
8.1	Flight
8.2	Laboratory
8.3	Meteorological
9	RESEARCH EQUIPMENT AND TECHNIQUES
9.1	Equipment
9.1.1	Wind Tunnels
9.1.2	Free-Flight
9.1.3	Towing Tanks and Impacts Basins
9.1.4	Propulsion Research Equipment
9.1.5	Propeller
9.1.6	Materials
9.1.7	Structures
9.2	Technique
9.2.1	Corrections
9.2.2	Aerodynamics
9.2.3	Hydrodynamics
9.2.4	Loads and Construction
9.2.5	Propulsion
9.2.6	Operating Problems
9.2.7	Mathematics
10	NOMENCLATURE
11	BIBLIOGRAPHIES
12	TECHNICAL SUMMARIES

Table G–6

System for Correlating Subject-Heading Numbers

In 1915–1949 index	In later indexes
1.4.1	1.4.1
1.4.2	1.4.1
1.4.2	1.4.1.3
1.4.3	1.4.1.4
1.4.3.1	1.4.1.4.1
1.4.3.2	1.4.1.4.2
1.4.4	1.4.2
1.4.4.1	1.4.2.1
1.4.4.2	1.4.2.2
1.4.4.3	1.4.2.3
1.4.4.4	1.4.2.4
1.4.5	1.4.3
1.4.6	1.4.4
1.4.7	1.4.5
1.4.8	1.4.6
1.4.9	eliminated
1.4.10	1.4.7

Table G–7

Percentages by Subject of Entries in NACA Publications Index, 1915–1958

Subject heading	Total																					
By year (19)—		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Aerodynamics	59.0	25	17	63	50	23	30	49	41	46	50	46	48	59	56	50	48	50	58	60	56	47
Hydrodynamics	2.2	...	...	...	...	...	...	1	1	...	1	4	3	3	4	2	1	3	3	5	10	11
Propulsion	14.7	8	25	6	50	29	23	18	6	16	8	16	18	16	11	14	15	16	17	12	11	10
Structures	9.3	17	...	13	...	6	4	4	4	7	8	6	7	2	6	17	12	12	6	9	6	17
Materials	5.4	17	...	13	...	16	15	3	5	5	12	2	6	8	7	6	11	4	4	2	4	1
Meteorology	1.0	8	...	...	...	...	1	1	1	1	...	...	1	...	1	1	...	1	1	1	1	...
Operating Problems	2.5	...	8	...	...	3	2	5	21	8	7	6	4	2	6	2	3	4	3	2	3	4
Instruments	1.5	25	17	...	...	3	6	7	11	7	4	8	5	2	2	4	3	4	4	1	3	4
Research Equipment Techniques	4.3	...	25	...	...	16	18	11	10	8	9	10	8	7	6	4	6	7	4	7	5	4
Nomenclature	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bibliographies and Indexes	0.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Technical Summaries	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Subject heading	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
Aerodynamics	51	55	54	53	52	61	52	47	48	45	51	63	65	68	67	63	62	62	62	60	61	57	57
Hydrodynamics	9	1	11	2	3	...	2	7	3	4	3	2	2	4	1	1	2	1	1	1	1	2	2
Propulsion	15	12	9	14	16	10	12	13	17	32	16	15	14	11	15	14	16	16	16	16	14	15	14
Structures	12	13	13	13	10	8	15	14	13	10	10	8	7	7	7	9	8	9	10	10	10	11	11
Materials	2	4	4	7	5	8	7	7	7	8	8	4	5	5	3	6	5	4	5	4	5	7	8
Meteorology	...	...	...	1	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
Operating Problems	3	2	2	2	3	4	4	3	3	2	3	2	2	2	1	1	1	2	2	2	2	3	3
Instruments	2	2	2	2	4	3	2	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Research Equipment Techniques	5	9	6	6	5	4	3	5	5	5	5	3	3	2	3	4	5	4	4	4	4	4	3
Nomenclature	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bibliographies and Indexes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Technical Summaries	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Appendix H
Documents

The following documents in the history of the NACA have been selected both to reproduce important materials that are either unpublished or inaccessible and to show how NACA people thought and wrote on issues of great concern to them. Aside from minor corrections in spelling and grammar, the documents are reproduced in their original form, warts and all. To save space, much introductory and concluding matter has been deleted, as have portions considered unimportant or redundant.

1. *Aeronautics: Report of the Advisory Committee for Aeronautics for the Year 1909–1910* (London, 1910): 4–5 (excerpt).
2. W. I. Chambers, "Report on Aviation," app. 1 to *Annual Report of the Secretary of the Navy for 1912* (Washington, 1912): 155–69.
3. "Minutes of First Meeting of the Advisory Committee of the Langley Aerodynamical Laboratory, May 23, 1913."
4. House Joint Resolution 413, 63d Cong., 3d sess., 1 Feb. 1915.
5. Franklin D. Roosevelt to L. P. Padgett, 12 Feb. 1915, in House Committee on Naval Affairs, *National Advisory Committee for Aeronautics,* H. Rpt. 1423 to accompany H. J. Res. 413, 63/3, 19 Feb. 1915, pp. 2–3.
6. Memorandum on a National Advisory Committee for Aeronautics, forwarded by Charles D. Walcott to Senator Benjamin R. Tillman, chairman of the Committee on Naval Affairs, 1 Feb. 1915.
7. Brig. Gen. George P. Scriven to Advisory Committee for Aeronautics, 16 April 1915.
8. Josephus Daniels to the president, 30 Nov. 1915.
9. Woodrow Wilson to Josephus Daniels, 2 Dec. 1915.
10. Report of the Subcommittee on a Site for Experimental Work and Proving Grounds for Aeronautics, 23 Nov. 1916, excerpted from minutes of Executive Committee meeting, 23 Nov. 1916.
11. Minutes of meeting of the NACA Subcommittee on Patents, 10 July 1917.
12. John F. Hayford, "Statement of Policy," 28 April 1917, as adopted by the Executive Committee 7 Aug. 1917 and by the NACA 4 Oct. 1917.
13. Lee M. Griffith to Executive Committee, 4 April 1918.
14. George de Bothezat to Subcommittee on Buildings, Laboratories and Equipments, 15 Feb. 1919.
15. L. C. Stearns to Joseph S. Ames, 5 April 1919.
16. Research Authorization No. 201, 21 Jan. 1927.
17. Memorandum of the Special Committee on Organization of Governmental Activities in Aeronautics [11 Feb. 1920].
18. "A National Aviation Policy," *NACA Annual Report, 1920,* pp. 54–56.
19. Report of the NACA Subcommittee on Federal Regulation of Air Navigation, 9 April 1921, from *NACA Annual Report, 1921,* pp. 13–15.
20. "Report of Proceedings of Second General Conference between Representatives of Aircraft Manufacturers and Operators and National Advisory Committee for Aero-

nautics," held at Langley Memorial Aeronautical Laboratory on 24 May 1927, undated.

21. Memorandum, George W. Lewis to General [Herbert M.] Lord, "Some Accomplishments of the National Advisory Committee for Aeronautics," 13 Sept. 1928.
22. Frank A. Tichenor, "Why the N.A.C.A.?" *Aero Digest* (Dec. 1930), 47 ff.
23. Memorandum, Elton W. Miller to Engineer-in-Charge, "Article in Aero Digest for December," 19 Dec. 1930.
24. Memorandum, H.J.E. Reid to George Lewis, "Comments on the Article in the December 1930 issue of Aero Digest, entitled 'Why the N.A.C.A.?' " 2 Jan. 1931.
25. Minutes of the NACA annual meeting, 22 Oct. 1931, pp. 10–13, adoption of rules governing work done by NACA for industry.
26. Orville Wright to John Victory, 6 Nov. 1931.
27. Joseph S. Ames to F. H. LaGuardia, 24 Feb. 1932.
28. "Economic Value of the National Advisory Committee for Aeronautics," Jan. 1933.
29. The Brookings Institution, "Memorandum on Report No. 12 on Senate Select Committee Making Recommendations Relative to National Advisory Committee for Aeronautics," 8 Nov. 1937.
30. Westover committee report, 19 Aug. 1938.
31. H. H. Arnold to George W. Lewis, 5 Jan. 1939, enclosing "Discussion of a Proposal to Establish an Aeronautical Laboratory for Applied Research."
32. Memorandum, John F. Victory to Dr. Lewis, "General Arnold's letter of January 5, 1939, re basic research, applied research, and production research," 9 Jan. 1939.
33. Jerome C. Hunsaker, "Memorandum on Postwar Research Policy for NACA," 27 July 1944.
34. "Notes on discussion at meeting of NACA, July 27, 1944," 8 Aug. 1944.
35. "Notes of discussions at meeting of National Advisory Committee for Aeronautics, April 26, 1945," undated.
36. "National Aeronautical Research Policy," approved 21 March 1946.
37. National Advisory Committee for Aeronautics, "A Proposal for the Construction of a National Supersonic Research Center," April 1946.
38. Langley Memorial Aeronautical Laboratory, "Appraisal of German Research during the War Relative to That of the NACA" [Oct. 1946].
39. "Report of the Director of Aeronautical Research submitted to the National Advisory Committee for Aeronautics at its annual meeting, October 23, 1947."
40. "Functions and Responsibilities of Standing Committees and Subcommittees of the National Advisory Committee for Aeronautics," 1 Jan. 1950.
41. Ira A. Abbott, memorandum, "Improvement of Laboratory Inspections," 14 June 1949.
42. "NACA Policy on Release of Proprietary Information," adopted by the NACA 16 June 1949, amended 16 Dec. 1949.
43. "A Report to the Industry on the Work of the NACA Industry Consulting Committee," 30 Dec. 1949.
44. "Policy for Operation of Unitary Wind Tunnels on Development and Test Problems of Industry," approved by the NACA 6 May 1953 on recommendation of the NACA Panel on Research Facilities.
45. "A National Research Program for Space Technology," a staff study of the NACA, 14 Jan. 1958.
46. "A Program for Expansion of NACA Research in Space Flight Technology with Estimates of the Staff and Facilities Required," 10 Feb. 1958.

1. Aeronautics: Report of the Advisory Committee for Aeronautics for the Year 1909-1910 (London, 1910): 4-5 (excerpt).

[The British Advisory Committee for Aeronautics was the model for the NACA. The composition of the committee—representatives of government agencies involved in aeronautics as well as civilian specialists—and the proposed areas of committee study exactly parallel those of the NACA.]

REPORT FOR THE YEAR 1909-10

To the Right Honourable H. H. Asquith, M.P., First Lord of the Treasury

SIR:—

The Advisory Committee for Aeronautics, appointed on April 30th., 1909, have since that date held ten meetings, of which one was at the Balloon Factory, Aldershot, one at the works of Messrs. Vickers, Sons & Maxim at Barrow, two at the National Physical Laboratory, and the remainder at the War Office.

The work for which the Committee was appointed was defined in the announcement made by the Prime Minister in the House of Commons on May 5th, 1909, which was as follows:—

> "The Government is taking steps towards placing its organization for aerial navigation on a more satisfactory footing. As the result of a report made by the Committee of Imperial Defence, the work of devising and constructing dirigible airships and aeroplanes has been apportioned between the Navy and the Army. The Admiralty is building certain dirigibles, while certain others of a different type will be constructed at the War Office Balloon Factory at Aldershot, which is about to be reorganized for the purpose. The investigation and provision of aeroplanes are also assigned to the War Office. With a view to securing that the highest scientific talent shall be brought to bear on the problems which will have to be solved in the course of the work of the two departments, the National Physical Laboratory has been requested to organize at its establishment at Teddington a special department for continuous investigation—experimental and otherwise—of questions which must from time to time be solved in order to obtain adequate guidance in construction.
>
> "For the superintendence of the investigations at the National Physical Laboratory and for general advice on the scientific problems arising in connection with the work of the Admiralty and War Office in aerial construction and navigation, I have appointed a special Committee, which includes the following names:—President: The Right Hon. Lord Rayleigh, O.M., F.R.S.; Chairman: Dr. R. T. Glazebrook, F.R.S. (Director, National Physical Laboratory); Members: Major-General Sir Charles Hadden, K.C.B. (representing the Army), Captain R.H.S. Bacon. R.N., C.V.O., D.S.O. (representing the Navy), Sir G. Greenhill, F.R.S., Dr. W. N. Shaw, F.R.S. (Director of the Meteorological Office), Mr. Horace Darwin, F.R.S., Mr. H. R. A. Mallock, F.R.S., Professor J. E. Petavel, F.R.S., and Mr. F. W. Lanchester."

On May 20th, the following further statement was made, in reply to a question from Mr. Balfour:—

> "It is no part of the general duty of the Advisory Committee for Aeronautics either to construct or invent. Its function is not to initiate, but to consider what is initiated elsewhere, and is referred to it by the executive officers of the Navy and Army construction departments. The problems which are likely to arise in this way for solution are numerous, and it will be the work of the Committee to advise on these problems, and to seek their solution by the application of both theoretical and experimental methods of research."

The work desired thus falls into three sections:

1. The scientific study of the problems of flight, with a view to their practical solution.

2. Research and experiment into these subjects in a properly equipped laboratory, with a trained staff.

3. The construction and use of dirigibles and aeroplanes, having regard mainly to their employment in war.

The Advisory Committee are to deal with the first section, and also to determine the problems which the experimental branch should attack, and discuss their solutions and their application to practical questions. The second section represents the work referred to the Laboratory, while the duties connected with the third section remain with the Admiralty and the War Office. . . .

2. W. I. Chambers, "Report on Aviation," app. 1 to Annual Report of the Secretary of the Navy for 1912 (Washington, 1912): 155–170.

[Chambers, one of the earliest advocates of a national aerodynamical laboratory, set forth in this report the arguments of national prestige and security behind the movement for a laboratory. He noted the European—especially the British—advances already made, described how the laboratory should be organized and run, and recommended the Smithsonian Institution's Langley laboratory as the logical nucleus. This last recommendation set off a bureaucratic struggle that delayed establishment of a national laboratory for several more years. Chambers's report remains the clearest and most prophetic single statement of the rationale for a national laboratory and its organization.]

BUREAU OF NAVIGATION, NAVY DEPARTMENT,
Washington, September 21, 1912.

From: Capt. W. I. Chambers, United States Navy.
To: The Bureau of Navigation, Navy Department.

Subject: Report on aviation.

The status of aviation in the world to-day may be summarized as follows:

The work of established aerodynamic laboratories has transported aeronautics generally into the domain of engineering, in consequence of which aviation has reached a stage of development wherein the methods of scientific engineers have replaced the crude efforts of the pioneer inventors.

The development of aviation for marine or naval purposes has naturally been somewhat delayed, but, inspired by the early demonstrations of our Navy, the naval powers of the world are now devoting large sums of money to this phase of development. It may be asserted that although the aeroplane has not yet arrived at the state of perfection required by all the work contemplated for it in naval warfare, yet it is sufficiently advanced to be of great service in many ways, should it be required for use in emergency, and its satisfactory development for extensive use is fairly in sight.

Those who are engaged in the development of aviation for war purposes do not pretend that it is going to revolutionize warfare, but it has been fully demonstrated that of two opposing forces, the one which possesses superiority in aerial equipment and skill will surely hold a very great advantage.

CONTEMPLATED USES OF AEROPLANES IN NAVAL WARFARE

A. They can be carried, stowed, and used by all large ships—

(1) To reconnoiter an enemy's port or to search out his advanced bases and to assist in the operations of a blockaded or a blockading force.

(2) To locate and destroy submarine mines, submarines and dirigibles, and to assist in the operations of submarines and torpedo boats.

(3) To damage an enemy's docks, magazines, ships in repair or under construction, dirigible sheds and other resources.

(4) To provide means of rapid confidential communication between a fleet commander and the commanding officer of a cooperating force on shore, or the commander of another fleet or division.

B. They can be carried by all scouts and large cruisers to extend the "eyes of the fleet" in naval scouting.

C. They can be carried, with ample supplies and camp outfit, on board any naval supply auxiliary for scouting at advanced bases and for extensive use with expeditionary forces.

WHAT IS BEING DONE ELSEWHERE

France leads the world in aviation, and all that she does is worth noting. A short time ago, in response to an inquiry by the minister of war, over 3,000 officers signified their desire to learn aerial navigation. Germany leads in aerostation, but is making great progress in aviation also. France has 8 dirigibles, Germany 30. The number of aeroplanes actually possessed by each is a rapidly increasing quantity, but France will probably possess about 350 before the end of the year, the ultimate aim being to possess 1,000 as soon as the requisite number of pilots can be taught to use them.

It is significant of German foresight that one of the first steps undertaken, when it was decided to construct a large aeroplane fleet, was to found an aerodynamic laboratory. This is at Gottingen, where the best known course of instruction in aeronautics is ably conducted by Prof. Prandtl.

The following statement, while it does not include all large sums that are being spent, will suffice to compare our own activity with that of some of the principal powers:

	Government appropriation	Popular subscription	Total
France	$6,400,000	$1,000,000	$7,400,000
Germany	1,500,000	750,000	2,250,000
Russia	5,000,000	(?)	5,000,000
Great Britian	2,100,000	(?)	2,100,000
Italy	2,000,000	100,000	2,100,000
Japan	600,000	(?)	600,000
United States	140,000	....	140,000

Exact details are lacking of the progress in many other countries, but all progressive powers are bent on keeping abreast of the times, especially the British colonies, Russia, Japan, and Austria. The latter country has produced one of the very best aeroplanes in existence, the Etrich, and is also developing the hydroaeroplane.

DEVELOPMENT IN THE UNITED STATES NAVY

When Congress appropriated $25,000 for the development of naval aviation last year, three officers had been ordered to aeroplane factories for instruction, in anticipation of three machines which were finally purchased, two Curtiss and one Wright.

At that time a land aerodrome was necessary for practice, and a hangar was accordingly built on Greenbury Point, Annapolis, Md., where a sufficient area of flat land was prepared for an aerodrome by the leveling of some trees and the partial filling of a swamp. This served its purpose until the Navy machines had all been provided with hydroplanes and we had demonstrated the practicability of carrying on instruction entirely over water. The aerodrome is now held in reserve for the housing of spare machines, for the exercise of the land attachment of the hydroaeroplanes and for any other emergency use.

It was originally contemplated to establish an aviation school in conjunction with the naval engineering experiment station, where experiments could be expedited, but it soon became apparent that the desired number of officers and men could not be spared away from their regular duties for a sufficient period and that the progress of instruction would be seriously delayed until the machines had been suitably developed and equipped for issuing to ships of the fleet, where practical instruction could proceed, with ample resources, in a systematic routine way. Incidentally, it was recognized that to get good service from these machines in the fleet constant practice would be required and the personnel be made as familiar with them as with other articles of equipment.

This was the first object in favoring the hydroaeroplane attachment.

To-day it is recognized the world over that hydroaviation offers one of the most promising fields of development, for the reason that a water aerodrome is nearly always available, is safer in landing, is less obstructed, and the aerial currents over water are less treacherous than over land. A ship provided with aeroplanes will thus become the hangar and will be surrounded usually by an ideal aerodrome, i.e., by water sufficiently smooth for practice.

Last December the three machines with their aviators were transferred to San Diego, Cal., where a camp was formed with small tents from the U. S. S *Iris* and hangar tents of the Army pattern, which had been prepared at the Mare Island Navy Yard.

Experience with these tents demonstrated certain defects and that they were not conducive to efficient progress with a small force of men. Better tents, designed by the Bureau of Construction and Repair, have been made to replace them.

After a season of winter work at San Diego the camp was transferred again to Annapolis, and located nearer the engineering experiment station on the north shore of the Severn River. This experience with tents has demonstrated that they not only facilitate the removal of a camp from one place to another, but that it is cheaper to use them than to provide permanent sheds of more durable material at all the places where a camp may be established. The use of tents also enables us to be prepared, with the advantage of experience, to transport at short notice all the material that may be required at an advanced base.

INSTRUCTION AND TESTS

Many officers interested in this work have applied for instruction, but, as before mentioned, it had not been possible to detach from their regular duties, even temporarily, all who desire the experience. Eight officers have qualified.

At the end of August, 1912, a total of 593 flights had been made by the four instruction aviators in the three machines. The record stands as follows:

	Flights	Total time	Distance	Passengers carried
In Curtiss machines:				
		H m.	*Miles*	
Lieut. Ellyson	200	40 30	2,227	111
Lieut. Towers	202	37 2	2,035	100
In the Wright machine:				
Lieut. Rogers	132	33 54	1,530	52
Ensign Herbster	59	14 54	630	9
Total	593	126 20	6,422	272

During flights over water the aviator can usually count on a safe place to land. For this reason most of our hydro flying has been done at an altitude of about 500 feet. But as scouting and reconnaissance work will require flying at an altitude of about 3,000 feet, Lieut. Ellyson has demonstrated that there will be no difficulty in flying the hydroaeroplane at 3,000 feet or over. On one occasion he ascended to 2,850 feet in 23 minutes and 25 seconds. On another occasion, in testing a lower grade of gasoline, he ascended 3,200 feet, but it required 44 minutes to reach the first 2,500 feet. Investigation of the different grades of gasoline shows that the difference in efficiency is considerable.

The longest flight yet made with passenger anywhere in the hydroaeroplane is that made by Lieuts. Ellyson and Towers jointly, from Annapolis, Md., to Hampton Roads, Va., and return, and this flight amply demonstrated three things: (1) The suitability of the "hydro" as a type for long flights; (2) the practicability and utility of the dual system of control; and (3) the necessity for greater improvement in motors. The return flight was enlivened, in very cold weather, by a series of minor mishaps to the motor. In making such flights it is still advisable to follow a shore line convenient for landing in case of motor trouble.

Lieut. J. H. Towers, United States Navy, has recently made a flight of 6 hours, 10 minutes, and 35 seconds with the standard Navy Curtiss hydroaeroplane. This was made in due course of regular work, but it stands as a world's record for flight in a hydroaeroplane and the American endurance record for flight in any kind of a machine. A performance of five hours only would have been satisfactory.

As a part of the instruction and a fruitful means of informing us concerning necessary improvements many repairs have been made by the aviators themselves, and the enlisted mechanics detailed for the purpose have received instruction in this way. A new Wright machine has also been built in this way from spare parts purchased from the company.

It has not been possible, under the circumstances of a meager appropriation and few officers, combining instruction with experimental work, to establish a thoroughly satisfactory system of instruction as yet. The ideal would require each aviator student to obtain a course of study in aerodynamics and meteorology up to date of about four months, such as that recently established at the Massachusetts Institute of Technology, the theory preceding the practical work, if possible. Such a course would be best attained by the establishment of a school for aviators in connection with the lectures at a national aerodynamic laboratory.

Experimental work.—The work of instruction has been handicapped by a practically continuous series of experiments, with the result that long delays in repairing have rendered work in both particulars slower than was anticipated. On the whole, this method of experimentation for the solution of problems other than the improvement of minor structural details and the test of navigating instruments is very unsatisfactory. Important experiments involving physical research should be relegated to an aerodynamic laboratory and its aerodrome annex. Other important experiments, such as the development of wireless, requiring frequent changes, should be made at an air-craft factory, where extensive repairs and reconstruction are facilitated. Special facilities already exist for doing such work at the Washington Navy Yard.

Some experimental work has been done on different methods of installing the wireless plant, but intermittently, owing to the enforced absence of the expert officer, whose suggestions were being followed. Although the work is unfinished, it has given promise of realizing a range of 50 miles at a sacrifice of 50 pounds only in weight.

Most of the experiments have been devoted to improving mechanical details of the motors and to trying different models of hydroplanes, the result of laboratory investigation at the model basin.

Much useful information has been gained thus about hydroplanes and many uncertain but alluring ideas have been eliminated. There are seven different types of hydroaeroplanes now in France, but our efforts have been confined chiefly to two distinct American types, the single boat with balancing pontoons and the catamaran type with two pontoons. Both types have given great satisfaction, but the single boat, which has been used on both the Wright and the Curtiss machines, seems best for our purposes. It is superior in rough water and it is the father of the flying boat, toward which our ideas have always been inclined.

The flying boat was discussed in the early days, about 1905, between Mr. Glenn H. Curtiss and representatives of the Bureau of Equipment. The first real flying boat was made and tested at Hammondsport, N. Y., a year ago last summer, and flown last winter at San Diego, Cal. After several alterations in the location of the motive power, the Curtiss flying boat tested this summer, with great satisfaction, by Lieuts. Ellyson and Towers, is regarded as a decided advance in hydroaeroplane design and gives promise of extended usefulness in rough water.

Catapult.—Tentative experiments with a compressed-air catapult for sending aeroplanes in flight over the shortest possible track have been made and their early completion is expected to avoid requiring a ship to carry a demountable platform.

The practicability of sending aeroplanes in flight from a suitable platform on board ship was early demonstrated by Eugene Ely in flights from the U.S.S. *Birmingham* and the U.S.S. *Pennsylvania.* We have frequently demonstrated the practicability of sending them in flight from water alongside of a ship, and both Mr. Glenn H. Curtiss and Lieut. John Rodgers have flown alongside of a ship, have been hoisted on board and hoisted out again in a hydroaeroplane. Lieut. Ellyson has successfully performed the daring experiment of showing the possibility and facility with which a hydroaeroplane can be sent in flight from a ship in smooth water over an improvised single wire cable, but I would not recommend the use of this device on a ship with rolling motion. Lieut. Ellyson also eagerly subjected himself in a hydroaeroplane to the extreme shock of the catapult device in order to test the effect of such a shock not only on the aviator but on the motor attachments and other fittings. This crucial test was entirely satisfactory in its revelations, although the aviator and machine got a ducking, and it will probably never be required again.

There is no risk that these zealous aviators will not cheerfully undertake in the interest of adapting the art of aviation to naval purposes, and it is worthy of note that the work has progressed thus far without serious accident, although it has been arduous, dangerous, and replete with temptations for the aviators to rival many of the sensational performances that have resulted disastrously to contemporary pioneers in civil aviation.

A simple and convenient self starter is a practical necessity to the hydroaeroplane before issuing it for ship use. Several mechanical devices have been tried with varying success, but other more promising devices are about to be tried and there is reason to believe that the very best will soon be in use on all of our machines.

Instruments.—Aviators and manufacturers have been slow in making use of instruments which not only make flying safer, but which may be made to relieve the aviator of much of the nervous tension and strain of long flights and flying in uncertain weather. A constant increase in the number of disasters has disturbed the people of France for some time, with the result that special attention has been given to the problem of safety; special efforts have been made not only to improve inherent stability and structural strength, but to provide means for controlling the equilibrium automatically.

One can not blame those who are already skilled in flying for being conservative in this matter, in view of the many defective devices that have been exploited to effect the object. There is good reason for going slowly and carefully in the test of anything that presumes to take the place of the aviator's skill, but manufacturers and aviators are beginning to realize that progress in aviation is greatly dependent upon the perfection of instruments for safe guidance and automatic control, that there is something more than acrobatic skill required to place aviation on a practical footing in the Navy, that the elimination of man as a factor of chief importance by the supply of mechanism which will perform the things that he is prone to do indifferently, especially under the strain of fatigue, is a practical necessity to his success as a real aerial navigator.

Simple and reliable automatic control devices which may be added without sacrifice of too much weight are now being eagerly sought and some that may be rigged to work automatically, semi-automatically, or not at all, at the will of the aviator, are being made.

The air compass.—Much important work for which the aeroplane will be useful in the Navy will not necessarily require the air pilot to navigate in a fog or at night or out of sight of his base, but in sea scouting, which I think is destined to be one of his principal spheres of usefulness, the pilot may be caught in a fog, he may be obliged to navigate at night and will have to lose sight of his base frequently. It must be possible, therefore, to navigate as accurately in air as it is to navigate a ship by dead reckoning at sea.

Motors.—Improvements have been confined principally to the correction of small defects which have been made as soon as discovered. Much more could be said about what is still needed. When anything goes wrong or when trouble begins in a flight that promises well, some trifling detail of the motor is usually at fault, a small pin here, a pump connection there, but nearly always something new and unexpected. It was so with the early motors of automobiles and this thought inspires confidence in the perfection of aviation motors, although the demand is still greater for increased power or speed rather than reliability and durability.

Range of speed.—A weight-carrying aeroplane such as a hydroaeroplane necessarily needs a motor with considerable range of speed, and the same kind of motor is needed to reduce the danger of alighting. This is not the kind of a motor and combination of motor and surfaces that now wins the speed contest, such as that for the Gordon Bennett cup. I think aviation would be improved if the terms of future speed contests were arranged so as to require each contestant to go over the course twice, the second time at an average speed 20 per cent lower than his highest average.

Requirements.—A year ago our manufacturers requested specific information as to the conditions to be satisfied in adapting the aeroplane for naval use. The answers at that time were necessarily indefinite, but with the benefit of a year's experience we have been able to issue a set of "general requirements" sufficiently broad in scope to permit a wide latitude for ingenuity and improvement.

These requirements cover not only the peculiar conditions to be satisfied in naval aviation, but, for the first time, require our builders to show that their machines are designed in accordance with up-to-date practice. Builders are required to provide technical data which will eliminate from competition all who depend on haphazard methods. Complete stress diagrams under different conditions of load and all the fundamental characteristics, a knowledge of which is indispensable to an intelligent comparison of designs, are demanded. The stamp of approval is given to the introduction of improved methods for the automatic control of equilibrium, and our builders are encouraged to attain a high degree of efficiency, to improve the factors which govern safety, and nothing is demanded that may not be readily accomplished under the limitations of the art as it is generally understood at present.

UNSATISFACTORY LIMITS IN APPROPRIATIONS

In accordance with the policy of the department, as mentioned in the last annual report of the Secretary of the Navy, aeroplanes are now placed in the same category as other articles of a ship's equipment, and are appropriated for accordingly, the general architecture and constructional features being provided by the Bureau of Construction and Repair under its general appropriation "Construction and repair of vessels," and the motive power, including radio apparatus, being provided by the Bureau of Steam Engineering under the appropriation for "Steam machinery," it being intended that all bureaus will do their share in providing the specific parts which naturally come under their cognizance in the department organization.

It seems unnecessary to place a limit on aeroplanes under these appropriations when expenditure on boats, steam steerers, windlasses, boilers, and "all other auxiliaries," costing much more, is unlimited. No economy is effected by placing a limit on any one of the numerous items under these appropriations and no extravagance can occur by removing the limits on aeroplanes, because, regardless of limits, the amount of each appropriation remains the same, and expenditure on each item will be jealously guarded by the bureau concerned to carry on current work as necessities arise.

It is particularly unfortunate that the small limit of $20,000 is placed on aeroplane machinery under the Bureau of Steam Engineering, because our experience shows that each aeroplane used for instruction requires two motors to carry on the work effectively. This of course will be impossible under the present limit, as the expense of repairs is also comparatively great. The limit of $35,000 under construction and repair is unsatisfactory also.

INFLUENCE OF FOREIGN LABORATORIES

Little more than a year ago our knowledge of the effect of air currents upon aeroplane surfaces was almost entirely a matter of theory. The exact information available was so meager that aeroplanes were built either as copies, slightly modified, of other machines, or else by way of haphazard experiment. This state of affairs obtains to some extent in the United States to-day, although in Europe aeroplane construction is now largely based on scientific data obtained at notable aerodynamic laboratories.

The intuitive, hasty, and crude methods of the pioneer can not succeed in competition with the accurate and systematic methods of the scientific engineer, and it is beginning to dawn upon our perceptions that through lack of preparation for the work of the scientific engineer, i. e., through delay in establishing an aerodynamic laboratory, a waste of time and money, a decline of prestige, and an unnecessary sacrifice of human life has already resulted.

Students of aviation do not need to be informed of the practical necessity for aerodynamic laboratories. They have repeatedly pointed out, in aeronautical publications, the immense commercial advantages to be anticipated from the establishment of at least one in this country, and they have naturally expected that some philanthropic patriot of wealth and scientific interest would come to the rescue with a suitable endowment fund that would enable such work to be started in short order without Government aid. The fact that no patriot has responded is disappointing, in view of the large private donations that have done so much for aviation in France, but in my opinion, it simply indicates something lacking in the manner of disseminating information concerning the importance of the subject. I am not willing to believe that our people will refuse to establish one when they are fully acquainted with the advantages to humanity and to sane industrial progress, and when a reasonable concrete proposition is advanced for their consideration. It is now my purpose to submit such a proposition, and, in doing so, I will follow briefly, in general outline, the ideas advanced in an address to the Fifth International Aeronautic Congress by one of the greatest authorities in the world, the Commandant Paul Renard, president of the International Aeronautic Commission.

A NATIONAL AERODYNAMIC LABORATORY

Before considering the character of the work to be done and some details of the needed plant, it will facilitate matters to show what should not be done at such a laboratory.

There are those who dream of supplying the laboratory with all the instruments known to mechanics, to physics, and even to chemistry, in order to have a creditable and complete national institution. They would concentrate in one locality all the scientific instruments and acumen available, with the false idea that economy would result. This would be a grave error.

The financial resources, however great, are sure to be limited, and a too ambitious or a superfluous installation would squander the sources of power and indirectly menace the initiative of other industries. The character of the new work to be done demands that everything should be rejected that can be dispensed with readily in order that appliances specially needed in the new work may be provided and that these appliances be of the latest and most efficient types.

For the sake of economy, not only of money but of time and intellectual energy, tests and experiments that can be executed as well or better elsewhere by existing establishments should be avoided. For example, it is unnecessary to install a complete set of instruments and implements for testing the tensile strength of materials or their bending and crushing strength. Many other establishments permit of such work. If the laboratory be located in Washington, where certain advantages exist such work could be readily done at the navy yard, where other facilities exist such, for instance, as the testing of models for hydroaeroplanes and flying boats. The Bureau of Standards and Measures and other Government branches in Washington also offer facilities which it would not be wise to duplicate in such a laboratory.

I do not think that such an institution should be burdened with measuring the power of motors or preoccupied with the details of their performances. This may be done at various other Government establishments, and it is understood that the Automobile Club of America is also equipped for this work.

Nor is it necessary to have a complete chemical laboratory under the pretext of studying questions relating to the chemistry of fuel or the permeability of balloon envelopes.

I do not wish to convey the idea that an aerodynamic laboratory should be deprived entirely of such facilities and that it should be obliged to seek minor information from other establishments when that information may be more economically obtained by a duplicate plant on a small scale. Such duplicate conveniences, however, should be regarded as strictly accessory; but it should be well understood that whenever important researches can be prosecuted as well or better elsewhere, dependence should be placed on those other establishments where such work is a specialty.

TWO DISTINCT CLASSES OF WORK

An aerodynamic laboratory should be devoted to (1) experimental verification, (2) experimental research. The first is concerned with testing the qualities of existing appliances, propellers, sustaining surfaces, control mechanism, etc. Usually these tests are made at the request of interested parties (as is now the case with water models at the navy-yard model basin). A constructor or a designer will bring, for example, a propeller and will wish to know its power or thrust at a given speed on the block or on a moving appliance under the conditions of flight, or he may bring several propellers to compare their performances and to ascertain what power they absorb at different speeds.

One of the very successful appliances devoted to this work at St. Cyr is a movable car, in which an aeroplane may be mounted and tested at speeds in perfect safety as to its strength, its efficiency, and the suitability of its control mechanism. This device is specially adapted to make actual service tests of sustaining surfaces, in other words, to try out in perfect safety the relative efficiencies of finished aeroplanes. It is a most important adjunct, as it supplements and rounds out the important research work on models in the closed laboratory.

Tests of this character, i.e., verification tests, constitute, so to speak, standard work. They are performed at the request of manufacturers, clubs, independent investigators, and other interested parties on condition of payment for the actual cost of the work. They therefore contribute to the support of the establishment.

The tests of verification, however, notwithstanding their great utility, do not constitute either the most important or the most interesting work of the laboratory. The research work, which prosecutes continuously and patiently systematic, thorough, and precise investigation of new ideas, or of old ideas with new applications, with the specific intention of discovering laws and formulas for advancing the progress of aerial navigation, is of greater importance, because it is the short cut to substantial efficiency, economy, improvement, and prestige.

This work is concerned with developing adequate methods of research in all branches of aerial navigation and in furnishing reliable information to all students, engineers, inventors, manufacturers, pilots, navigators, strategists, and statesmen. The knowledge thus gained should be disseminated regularly through publications, lectures, open-air demonstrations, and by exhibitions of apparatus, instruments, materials, and models—in fact, by all the facilities of the aerodrome, the showroom, the library, and the lecture room.

An exact knowledge of aerodynamics can best be acquired in such a laboratory by experimentation with standard scale models in air tunnels such as those used by M. Eiffel and others. In this way reliable data is obtained of the air resistance to be encountered and the efficiency at various velocities, the amount of lift, the effect of varying impact at different angles of attack on the stability—in fact, all the exact data which, reduced to curves and diagrams, enables the engineer to design a machine in a scientific manner. From such data the performance of a new machine can be closely predicted. The performance of the finished product can be verified later as before described.

Much of the research work will be prosecuted at the request of technical men outside of the institution, to whom the laboratory should offer, gratuitously as far as possible, its material and personal resources.

THE COUNCIL AND ORGANIZATION

To obtain benefit from these researches it will be necessary to know that they are worth the time and expense, and a body of men—a council or a board of governors—should be authorized to accept or reject requests for this work. This will be a delicate task, but the principal duty of the council should be to establish and to correct from time to time a program of the research work to be executed by the director and his staff and to coordinate the work to the best advantages within the limits of the money available. The disbursement of the Government funds, however, and the responsibility therefor should be entirely under the director.

With the actual state of aerial navigation and its deficiencies as a guide it will be the policy of the council to concentrate effort upon such points as seem most important, promising, and interesting for the time being.

I do not think there would be any doubt, if we had the laboratory in working order now, but that all questions relating to improvement in stability, automatic control, and safety in general would have the right of way.

The council or board, which in England is called the "advisory committee," should be representative of other Government departments than that employing the director, and should be independent of the director and his administrative staff. It might be possible for the director to act as a member of the council, and, if so, it would conduce to harmony and expedition.

The council should not be a large body, but should be composed mostly of specialists of unquestioned ability, men interested in the sane development of aerial navigation in various branches of the Government and in its useful and safe adaptation to commerce and sport.

Whatever the ability of this council it should not be allowed to pretend that it has a monopoly of aeronautic acumen. Many brilliant and worthy ideas may originate outside of the establishment which it will be wise to investigate. And to avoid any possibility of the council being charged with narrow prejudice, it is indispensable that it be not composed entirely of specialists. In a few words, it should comprise representative men who are also learned and technical men, with broad vision and reputation, whose presence will guarantee to industrial investigators that their ideas will be treated in an unpartisan or unbiased spirit. I will not attempt to suggest the composition of this council or board, but it is evident that the Army and Navy should each be adequately represented on it.

ENDOWMENTS, PRIZES, AND REWARDS

If the laboratory should obtain, in addition to the funds required for prosecuting researches by its staff, any endowments of financial aid in excess of immediate needs (and I am confident it will eventually), it would accomplish useful work by offering prizes and granting rewards for important results achieved outside of the institution. The division of rewards would be one of the functions of the council, and it is possible that this would be one of the best uses of such resources, after the success of the laboratory is assured.

The complete role of an ideal aerodynamic laboratory can be summed up now in a few words in the natural order of establishment: (1) Execution of verification tests by means of nominal fees; (2) facilities to technical men for prosecuting original research; (3) execution of researches in accordance with a program arranged by the council, and (4) reward of commendable results accomplished outside of the laboratory.

NATURE OF THE PLANT

Researches and tests can be made on either a large or a small scale, preferably on both.

The use of small models can be made prolific in results because of the comparatively small cost, provided we understand the laws governing transformation into the full sized products. For model work a large plant is unnecessary. M. Eiffel has done very valuable work in a very small establishment.

Certain classes of tests with large models, such, for example, as the block test of propellers, do not require much space. But the conditions are altered when such tests are made on a machine in motion. These more difficult tests are absolutely indispensable and very important to the usefulness of an official laboratory.

Experiments and tests with small models being comparatively inexpensive, private establishments often undertake their execution, but when we attempt to draw conclusions from their results we are obliged to admit that the laws of comparison with full-sized machines are debatable the world over. Comparisons are sensibly true between small surfaces and larger surfaces that have been extended proportionately to the square of the linear dimensions, even to surfaces five or ten times larger, but when we pass to much larger surfaces, as we are obliged to, we are forced to adopt formulas with empirical coefficients, about which there is indefinite dispute.

The difficulty can be overcome only by precise experiments upon large surfaces, and such experiments, whatever the manner in which they are performed, will be costly. If privately executed, the financial returns would not cover the cost.

The laboratory should comprise, therefore, two distinct parts, one devoted to experiments on small-scale models and the other to experiments on surfaces of large dimensions. But in both parts precise and thorough work is necessary.

When we have studied separately each element of an aeroplane, for example, it will be necessary to test the complete apparatus. An aerodrome annex is therefore necessary, or, at least, the laboratory should be located in proximity to an aerodrome of which it can make use. In order that the observations may not only be qualitative but quantitative, it will be necessary to follow all the movements of the complete machine to know at each instant the speed, the inclination, the thrust of the propellers, the effective horsepower, and, in fact, to conduct a true open-air laboratory for air craft after the manner of certain tests that have been prolific of results in France.

The English have established close relations between the royal aircraft factory and their laboratory, the function of the former being the reconstruction and repair of aeroplanes, the test of motors, and the instruction of mechanics.

LOCATION OF THE LABORATORY

The location of the model-testing plant, the headquarters of the administration staff, requires comparatively small space, and there is no reason why it should be remote from a city or from intellectual and material resources. It is advantageous to have it easy of access to many interested people who are not attached to it.

The location of the open-air laboratory should obviously be at an aerodrome as near as may be convenient to the model-testing plant or headquarters. Close proximity of the two parts is desirable, but not necessary. The high price of land near a large city obliges the aerodrome annex of foreign plants to be located at a distance, but we are fortunate in having here at Washington ideal conditions for the location of both parts. The model laboratory should obviously be located on the site of Langley's notable work at the Smithsonian Institution, where the nucleus, an extensive library of records, and a certain collection of instruments, are still available. The National Museum is also an ideal location for the historical collection of models that will result.

No more ideal location for the annex, the open-air laboratory, or aerodrome exists in all the world than that afforded by the as yet undeveloped extension of Potomac Park. This is Government property which is of doubtful utility as a park only, but which would be of immense utility and interest as a park combined with a scientific plant of the character under consideration.

There is no reason why the public should be excluded from such a practice field, but there is much to recommend that it be open to the public under proper regulations as to the traffic, especially on occasion of certain tests or flights of an educational value. It is of sufficient area, about 1 square mile. It is about 2 miles long, is almost entirely surrounded by broad expanses of water, and, while convenient of access, is so situated that the public may be readily excluded when tests of a dangerous character are in process of execution. The fine driveways that will be required as a park will offer excellent facilities for the practice work of the aerodrome and for the moving test cars that should be supplied.

One of the most attractive features of this location is the advantage it offers as an ideal aerodrome for both the Army and the Navy, for both land and water flying and the opportunity it affords for cooperation in all branches of the work of instruction and experimentation. Furthermore, it is near to the shop facilities of the navy yard, the accommodations of the Washington Barracks, the conveniences of various Government hospitals, and it would doubtless add to the information and interest of the near-by War College Staff and the General Board of the Navy. Its location would enable our statesmen in Congress and a great number of officials in all departments to keep in touch at first hand with the progress of aeronautics, with the quality of the work done, and with the manner in which the money appropriated was being expended. The educational facilities afforded by the work and by the lectures would be invaluable to the course of intruction for Army, Navy, and civil students of aeronautics.

As Washington is a mecca for business people of all parts of the country, a laboratory located here would be convenient in a commercial sense, especially in view of its southerly location, which renders the open aerodrome available for use throughout the greater part of the year. The only objection that I can see to the Potomac Park extension is that the ground will require a considerable clearing, but the trees on the harbor side of the location would not necessarily require removal.

THE APPARATUS NEEDED

It is useless to discuss here the various instruments and methods which have been a source of some dispute abroad. All have some good feature, but time has shown where some of the cumbersome and unnecessary installations may be eliminated to advantage and where others may be improved. The new plant of M. Eiffel, at Auteuil, may be regarded as a model for the wind tunnel and the aerodynamic balance. A duplicate of that plant alone would be of inestimable value. The last volume published by M. Eiffel is a forcible example of the value of his discoveries by this method with respect to the angle of incidence and the displacements of the center of pressure. It seems to merit the utmost confidence, although the details of his installation differ from those at Chalais, at Koutchino, at the Italian laboratory, and others. This method permits of testing the resistance of body structures, the sustaining power of surfaces, the tractive power of propellers, and the influence of transverse or oblique currents. If a "free drop" apparatus at uniform speed be regarded as indispensable to obtaining the coefficients of air resistance to solid bodies of different shapes, it is possible that the interior of the Washington Monument could be used to advantage, as was the Eiffel Tower, without disturbance of the main function of that noble structure. This would be an excellent place from which to observe the stability or action of falling models cast adrift at an altitude of 500 feet under varying atmospheric conditions. The free drop of full-sized models would of course require the use of kites or captive balloons.

The moving car previously referred to for tests of verification would be the most useful open-air plant and would soon repay the outlay required by the value of the information obtained from its use. A miniature duplicate of this method for preliminary tests on models with a wire trolley would be of value in a hall of large dimensions. It would be useful in winter work but not invaluable.

The track of the open-air vehicle at St. Cyr is too restricted to give the best results. The car can not circulate continuously at high speed and maintain the speed for a sufficient length of time. An ideal endless track may readily be arranged at the Potomac Park extension, preferably of rectangular form with rounded corners. A railway track would be preferable, but excellent results could be obtained from auto trucks run on macadamized roadbeds. Good results could be obtained by the use of suitable hydroaeroplanes or flying boats suitably equipped with instruments.

At the aerodrome annex ample facilities should be provided for measuring the wind velocity at various heights and at different points. The convenient installation of recording anemometers and the employment of kites or captive balloons should be considered.

A branch of the United States Weather Bureau could readily be established at the aerodrome here in connection with the investigation of meteorological phenomena affecting the movements of aeroplanes in flight and as an adjunct to the national laboratory.

Exactly measured bases and posts of observation are also required, as well as instruments of vision or photographic apparatus, to permit of following machines in their flights and of preserving the records for study.

One of the most useful installations for recording advanced information is an actual aeroplane itself equipped with instruments adapted to record, while in flight, much of the information that is desired. Such machines are already in use in France and in England.

It will be in perfect harmony and convenient to the laboratory to obtain all the services of an aircraft factory from the Washington Navy Yard, where facilities already exist for the reconstruction and repair of aeroplanes, the test of motors, and the instruction of mechanics. But this should not be allowed to interfere with our policy of relying upon private industry for the purchase of new machines, for the sake of encouraging the art among private builders.

It will suffice to merely mention the hangars or sheds required or the local accessories, such as drafting room, office, and minor repair shops. The character and location of these present no difficulties, but they should not be made the principal part of the institution as they are in several elaborately equipped foreign laboratories. The power plant, however, is a subject for careful consideration and the economy effected by M. Eiffel in his new installation at Auteuil is worthy of study.

COST

I have seen estimates varying from $250,000 to $500,000 for such a plant, but inasmuch as $100,000, with an annuity of $3,000 donated by M. Henry Deutsch de la Meurthe to the University of Paris for the establishment of the aeronautical laboratory at St. Cyr, seems to have been sufficient for a very creditable though somewhat deficient plant, I will venture an opinion that $200,000 would be sufficient in our case. Although the same plant would cost more in this country, I assume that some of the buildings required are already available at the Smithsonian Institution. If located elsewhere the cost would be considerably more than the sum named.

A COMMISSION RECOMMENDED

Inasmuch as more definite information regarding the actual cost of a dignified and creditable but modest and sufficient installation should be obtained and as the details of the plan, the scope, the organization, and the location of such an important undertaking should not be left to the recommendations of one man, *I respectfully recommend that a commission or board be appointed to consider and report to the President, for recommendation to Congress, on the necessity or desirability for the establishment of a national aerodynamic laboratory, and on its scope, its organization, the most suitable location for it, and the cost of its installation.*

W. IRVING CHAMBERS.

3. Minutes of First Meeting of the Advisory Committee of the Langley Aerodynamical Laboratory, May 23, 1913.

[Smithsonian Secretary Charles D. Walcott reported on the steps leading to establishment of this forerunner of the NACA. In almost every respect, especially the composition of the committee and the immediate distribution of work among subcommittees, this meeting presaged the NACA's first meeting two years later.]

The Advisory Committee of the Langley Aerodynamical Laboratory was formally organized at a meeting at the Smithsonian Institution, at 10 A.M., May 23, 1913. The following is a list of members of the Committee, all of whom were present except Brig. General Scriven:

Captain W.I. Chambers, U.S.N.
Mr. Glenn H. Curtiss
Mr. John Hays Hammond, Jr.
Dr. W. J. Humphreys
Naval Constructor H. C. Richardson, U.S.N.
Major Edgar Russel, U.S.A.
Brigadier General George P. Scriven, U.S.A.
Dr. S. W. Stratton
Mr. Charles D. Walcott
Mr. Orville Wright
Dr. Albert F. Zahm

On motion, Mr. Charles D. Walcott was appointed temporary Chairman, and Dr. A. F. Zahm temporary Recorder of the Committee.

Mr. Walcott briefly outlined the events leading up to the re-opening of the Langley aerodynamical laboratory, as follows:

At the regular meeting of the Board of Regents of the Smithsonian Institution on February 13, 1913, the Secretary presented a scheme for the establishing of an aeronautical laboratory under the direction of the Smithsonian Institution. A committee consisting of Judge George Gray, Dr. Alexander Graham Bell, and Representative John Dalzell was appointed to consider the question, and also to consider the availability of any portion of the Hodgkins Fund for the purpose of said laboratory. This committee reported to the Board of Regents at a special meeting held on May 1, 1913, and recommended that the Secretary of the Smithsonian Institution be authorized to re-open the aerodynamical laboratory used by the late Secretary Langley in pursuing his researches relating to aeronautics, and the Board thereupon adopted the following resolutions:

"WHEREAS, The Smithsonian Institution possesses a laboratory for the study of questions relating to Aerodynamics which has been closed since the death of its Director, the late Dr. S. P. Langley, formerly Secretary of the Smithsonian Institution; and

WHEREAS, It is desirable to foster and continue, in the Institution with which he was connected, the aerodynamical researches which he inaugurated—

RESOLVED: (1) THAT; the Board of Regents of the Smithsonian Institution hereby authorizes the Secretary of the Institution, with the advice and approval of the Executive Committee, to reopen the Smithsonian Institution Laboratory for the study of Aerodynamics and take such steps as in his judgment may be necessary to provide for the organization and administration of the laboratory on a permanent basis.

(2) THAT; the aerodynamic laboratory of the Institution shall be known as the Langley Aerodynamical Laboratory.

(3) THAT; the functions of the Laboratory shall be the study of the problems of Aerodromics, particularly those of aerodynamics with such research and experimentation as may be necessary to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, National defense, and the welfare of man.

(4) THAT; the Laboratory, under regulations to be established and fees to be fixed by the Secretary, approved by the Executive Committee, may exercise its functions for the military and civil departments of the Government of the United States, and also for any individual, firm, association or corporation within the United States, provided, however, that such department, individual, firm, association or corporation shall also defray the cost of all material and services of employees in connection with such exercise of the functions of the said Laboratory.

(5) THAT; the Laboratory shall, with the approval of the Secretary of the Institution, issue bulletins and other publications for public distribution, containing such information as may be valuable to the Government or the public.

(6) THAT; there shall be a Director of the Laboratory, who shall be appointed by the Secretary, and who shall receive such salary as may be approved by the Executive Committee. The Secretary is also authorized to appoint assistants and other necessary employees.

(7) THAT; the Director shall have general supervision of the Laboratory. He shall make an annual report to the Secretary of the Smithsonian Institution. Said report shall include an account of the work done for any Department of the Government, individual, firm, association or corporation, and the amounts paid by them to defray the cost of material and services as hereinbefore provided.

(8) THAT; the Secretary may provide or rent such temporary quarters and obtain such permanent quarters as may be provided for by funds available or provided for the purpose.

(9) THAT; the Secretary is authorized to appoint an Advisory Committee, to be composed of the Director of the Laboratory when appointed and one member to be designated by the Secretary of War, one by the Secretary of the Navy, one by the Secretary of Agriculture, and one by the Secretary of Commerce, together with such other persons as may be acquainted with the needs of aerodromical science, the total membership of such Committee not to exceed fourteen in number.

(10) THAT; the Committee shall advise in relation to the organization and work of the Laboratory, and the co-ordination of its activities with those of other Governmental and private laboratories, in which questions concerned with the study of the problems of aerodynamics and aerodromics can be experimentally investigated. The members of the Advisory Committee shall serve without compensation, but shall be paid their actual necessary expenses in going to and returning from Washington to attend the meeting of the Committee and while attending the same.

THAT; the Secretary is authorized, with the approval of the Executive Committee, to open the Laboratory and begin its work, when funds are made available for the purpose, either by private contribution, Governmental appropriation, or the authorization by the Board of Regents of the use of funds that are now or may become available for appropriation by the Smithsonian Institution.

At the same meeting the following additional resolutions were also adopted by the Board of Regents:

RESOLVED: The Secretary is authorized, with the advice of the Executive Committee, to enlarge the approved scheme of the Langley Aerodynamical Laboratory under the direction of the Smithsonian Institution, by adding, as means are provided, other laboratories and other essential agencies, and to group the several laboratories and other agencies into a Bureau organization.

RESOLVED FURTHER: That all resolutions in relation to administration, personnel, direction, etc., that apply to the Langley Aerodynamical Laboratory, shall apply as far as practicable to the said Bureau of Aerodromics when established.

RESOLVED: The Secretary is authorized to use such portion of the accumulated income of the Hodgkins Fund as may be necessary in connection with the reopening and organization of the Langley Aerodynamical Laboratory, to an amount not to exceed ten thousand dollars.

RESOLVED FURTHER: The Secretary is also authorized to expend for the said purpose, the annual income from a restricted portion of the Hodgkins fund not to exceed five thousand dollars per year, for a period of five years.

RESOLVED: The Secretary is hereby authorized to visit such laboratories and institutions in Europe as will in his judgment be of service in the organization and administration of research under the direction of the Smithsonian Institution.

RESOLVED: The Secretary is authorized to associate with himself not to exceed three persons in examining and reporting on the principal laboratories and institutions engaged in aeronautical research, provided that the expenses of such examination and report shall not exceed $2,000.

RESOLVED: The Secretary is authorized to secure, as far as practicable, the cooperation of Governmental and other agencies in the development of aerodromical research under the direction of the Smithsonian Institution.

RESOLVED: The Secretary is authorized to submit an estimate to the Congress of fifty thousand dollars for the continuation of aerodromical (aeronautical) investigations under the direction of the Smithsonian Institution.

Mr. Walcott stated that in pursuance of the Board's action, he addressed the following letter to President Wilson:

SMITHSONIAN INSTITUTION,
Washington, May 8, 1913.

Sir:

I have the honor to state that at the special meeting of the Board of Regents of the Smithsonian Institution, held May 1, 1913, I was authorized, as Secretary of the Smithsonian Institution, to re-open the Langley laboratory for the study of aerodynamics, and to take such steps as may be necessary to provide for the organization and administration of the laboratory on a permanent basis.

The functions of the laboratory will be to study the problem of aerodromics (aeronautics), particularly those of aerodynamics, with such research and experimentation as may be necessary to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, National defense, and the welfare of man.

The Secretary was authorized to appoint an Advisory Committee and to request the cooperation of Governmental and other agencies in the development of the laboratory. The functions of this Committee will be to advise in relation to the work of the laboratory and the coordination of its activities with those of other governmental and private laboratories in which questions concerned with the study of problems of aerodromics (aeronautics) can be experimentally investigated.

I beg leave, therefore, to ask your approval of the cooperation with this Institution of the Departments of War, Navy, Agriculture, and Commerce, and if this meets with your assent, I have the honor to request that one member of the Advisory Committee be designated by the Secretary of War, one by the Secretary of the Navy, one by the Secretary of Agriculture, and one by the Secretary of Commerce.

In addition there will be appointed such other persons on the Committee as may be acquainted with the needs of aerodromical (aeronautical) science, the total membership not to exceed fourteen.

The members of the Committee shall serve without compensation, but shall be paid their actual necessary expenses in going to and returning from Washington to attend the meetings, and while attending the same, from a special fund at the disposal of this Institution.

It is desired to have a representative of the War Department and one from the Navy Department on the Advisory Committee to represent their aeronautical interests; to have a member from the Department of Agriculture to represent the Weather Bureau, as the subject of meteorology is one that has a profound bearing on successful aviation; and to have a member from the Department of Commerce to represent the Bureau of Standards, where in the near future it is hoped that systematic tests of materials, motors, etc., can be made under the direction of that Bureau.

I am, Sir,

Your obedient servant,

CHARLES D. WALCOTT,
Secretary.

The President,
The White House, Washington, D.C.

The following reply was received from the President:

THE WHITE HOUSE,
Washington, May 9, 1913.

My dear Doctor Walcott:

Allow me to acknowledge the receipt of your letter of May eighth, and to say that I shall take pleasure in sending copies of your letter to the Secretaries of War, Navy, Agriculture, and Commerce, expressing my full approval of the designation of representatives of those Departments upon the committee which you are forming for the study of the subject of aeronautics under the authorization of the Board of Regents of the Smithsonian Institution on May 1, 1913.

Cordially and sincerely yours,

WOODROW WILSON.

Dr. Charles Walcott,
Smithsonian Institution.

Letters were subsequently received by the Institution from the Secretaries of War and the Navy stating that on account of the magnitude of their aeronautical interests, it was thought advisable to designate two members from their respective Departments.

In accordance with the above, the following designations of members for the Advisory Committee were made by the heads of the Departments concerned:

WAR DEPARTMENT:

Brigadier General George P. Scriven, U.S.A., Chief Signal Officer of the Army.
Major Edgar Russel, U.S.A., Signal Corps, in charge of the Aeronautical Division of the Signal Office.

NAVY DEPARTMENT:

Captain W. I. Chambers, U.S.N., in charge of Naval Aviation.
Naval Constructor H. C. Richardson, U.S.N.

DEPARTMENT OF AGRICULTURE:

Dr. W. J. Humphreys, of the U.S. Weather Bureau.

DEPARTMENT OF COMMERCE:
Dr. S. W. Stratton, Director of the Bureau of Standards.

In addition to these, invitations were sent by the Secretary of the Institution to the following gentlemen who accepted membership on the Advisory Committee:

Mr. Glenn H. Curtiss
Mr. John Hays Hammond, Jr.
Mr. Orville Wright
Dr. Albert F. Zahm

Mr. Walcott also stated that invitations had been sent to Mr. Cornelius Vanderbilt and Mr. Harold F. McCormick, but these gentlemen, on account of press of business matters, were unable to accept membership.

After discussion it was decided that the term of service of all members and officers should be for one year, to expire on or about May 6th of each year, as may be determined later. In view of the fact that May 6th has in the past been generally designated as "Langley Day," it was suggested that the regular annual meeting of the Advisory Committee be held on May 6th, as it was thought probably that many of the members would be in Washington on that day.

On motion of Captain Chambers, Mr. Walcott was then elected permanent Chairman of the Advisory Committee, for one year.

On motion of Dr. Stratton, Dr. Zahm was elected permanent Recorder for one year.

The Chairman then informed the Committee that he was able to place at its disposal a room in the Smithsonian building which could be used by the Recorder and such assistants as he might have from time to time, and where all records of the Committee could be filed. It was suggested that a general letter-head be prepared for the Advisory Committee, the name of each subcommittee to be placed on this paper with a rubber stamp. The Chairman authorized the Recorder to have a stock of such paper prepared. Provision was also made for the employment of such translating and typewriting services as might be required by the Sub-Committees, and also for the use of Smithsonian franked envelopes for mailing communications relating to the work of the Laboratory.

The Chairman then presented a plan for the organization of a number of Sub-Committees, which, after minor changes, was unanimously approved by the meeting. A Chairman chosen from the members of the General Committee, was assigned to each Sub-Committee, with the authorization to add other members to his committee to the number of not more than four and not less than two, to be selected either from the General Committee or from other sources. It was resolved that the Chairmen of the Sub-Committees should report to the Chairman of the General Committee the names of members selected by them, and that they should make quarterly reports of the work of their Committees, these to be placed in the files of the General Committee, which would later publish an annual report. All of the members present who were appointed as Chairmen of Sub-Committees, signified their acceptance of the appointments.

The following is a list of the Sub-Committees, together with the Chairman appointed for each:

1. Sub-Committee on collection and correlation of aeronautical information. Dr. A. F. Zahm, Chairman, Smithsonian Institution, Washington, D.C.

2. Sub-Committee on publication and dissemination of aeronautical information. Dr. A. F. Zahm, Chairman, Smithsonian Institution, Washington, D.C.

3. Sub-Committee on aeronautical meteorology. Dr. W. J. Humphreys, Chairman, U.S. Weather Bureau, Washington, D.C.

4. Sub-Committee on comparative tests and standardization of instruments, motors, and propellers; tests of the tensile, compressive, and bending strengths, and elasticity, weight, etc., of various materials used in aeronautical construction, and

determination of aerodynamical constants. Dr. S. W. Stratton, Chairman, Bureau of Standards, Washington, D.C.

5. Sub-Committee on hydro-mechanic experiments in relation to aeronautics. Naval Constructor H. C. Richardson, Chairman, Washington Navy Yard, Washington, D.C.

6. Sub-Committee on naval air craft design. Captain W. I. Chambers, Chairman, Navy Department, Washington, D.C.

7. Sub-Committee on military air craft design. Major Edgar Russel, Chairman, U.S. Signal Corps, Washington, D.C.

8. Sub-Committee on field experiments with naval air craft. Captain W. I. Chambers, Chairman, Navy Department, Washington, D.C.

9. Sub-Committee on field experiments with military air craft. Brig. Gen. George P. Scriven, Chairman, U.S. Signal Corps, Washington, D.C.

10. Sub-Committee on air craft communication. Mr. John Hays Hammond, Jr., Chairman, Gloucester, Mass.

11. Sub-Committee on experimental air craft factory. Naval Constructor H. C. Richardson, Chairman, Washington Navy Yard, Washington, D.C.

12. Sub-Committee on laboratory buildings and equipment. Dr. C. D. Walcott, Chairman, Smithsonian Institution, Washington, D.C.

13. Sub-Committee on air craft appliances. Brig. Gen. George P. Scriven, Chairman, U.S. Signal Corps, Washington, D.C.

14. Sub-Committee on natural flight.

15. Sub-Committee on mathematical principles of aeronautics.

The appointment of Chairman for the two Sub-Committees above was left in abeyance.

16. Sub-Committee on Applied Aerodynamics. Dr. A. F. Zahm, Chairman, Smithsonian Institution, Washington, D.C. (Organized at meeting of June 23, 1913.)

The matter of bringing the membership of the General Committee up to the prescribed number of fourteen was discussed, but it was decided not to add to the number at present.

The Chairman informed the Committee that the Disbursing Office of the Smithsonian Institution can take charge of any money given for the use of the laboratory, or placed at the disposal of the Committee, either by individuals or by the Government, and disburse the same.

The Chairman, Mr. Walcott, expressed the wish of the meeting that the Chairman of each Sub-Committee should, as soon as practicable, ascertain what data, facilities, etc., are now available to his committee; what work is now going on, and what work should be initiated, this information to be reported to the Chairman of the General Committee.

It was the sentiment of the Committee that no funds should be expended for the development of patents, or for experimenting with patents, for the benefit of individuals.

The Recorder was requested to prepare a statement for publication, recounting the organization of the Committee, and setting forth its scope and purposes. He was also authorized to give the daily press an account of the first meeting.

The Chairman stated that a preliminary draft of the minutes of each meeting would be sent to each member for his approval, with an opportunity to make any corrections or comments desired.

It was decided that when the Committee adjourn, it meet again some time next month, when reports might be received from the various Sub-Committees as to the progress of their organization and work, the exact date of the meeting to be determined by the Chairman later and communicated to each member of the General Committee.

The Committee then adjourned.

(SIGNED) C. D. WALCOTT,
Chairman.

Attest:
(Signed) A. F. Zahm,
Recorder.

4. House Joint Resolution 413, 63rd Cong., 3rd sess., 1 Feb. 1915.

[The introductory paragraphs state the rationale for the actual resolution, which became (in almost exactly this form) the organic legislation of the NACA enacted as a rider on the naval appropriations bill for 1916. (See App. A.)]

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 1, 1915

Mr. ROBERTS of Massachusetts introduced the following joint resolution; which was referred to the Committee on Naval Affairs and ordered to be printed.

JOINT RESOLUTION

To authorize the appointment of an Advisory Committee for Aeronautics.

Whereas the United States is the only nation of the first class that does not have an Advisory Committee for Aeronautics to advise and direct in relation to experimental work of the Government, and to provide for the cooperation of governmental and private activities in relation to the unsolved problems of aeronautics; and

Whereas the United States invented and led in the early development of the heavier-than-air flying machine, but nothing being done by the Government to develop the art and to encourage and assist American inventors and manufacturers beyond the purchase of a few flying machines, and the establishment of a small plant at the Washington Navy Yard, it has fallen behind, owing to the policy of inaction and the lack of appreciation of the wisdom of utilizing all of the technical ability and the inventive genius of the Nation; and

Whereas under the guidance of an Advisory Committee for Aeronautics continuity of purpose and action in the development of this science and art is practically guaranteed, unaffected by the change of individuals in administrative positions in the executive departments of the Government; and

Whereas the expenditure of money appropriated could be more wisely made, and economies secured by the prevention of duplication of investigation and experiment, and the development of aeronautics in America placed upon a strong foundation through the influence of a suitable advisory committee; and

Whereas the establishment of such committee would be in the line of the best practice of European nations, such as Great Britain, France, and Germany, all of which have made remarkable progress in aviation under the spirit of cooperation of governmental and civil agencies; and

Whereas under existing law (section nine of the Act approved March fourth, nineteen hundred and nine, Thirty-fifth Statutes, page ten hundred and twenty-seven) it is unlawful for the President or any Government official to appoint a committee, commission, or board on aeronautics without authorization by Congress: Therefore be it

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That an Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed fourteen members, to consist of two members from the War Department, from the bureau in charge of military aeronautics; two members from the Navy Department, from the bureau in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than seven additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences, three of whom may be residents of the District of Columbia, and the others shall be inhabitants of some State, but not more than one of them from the same State: *Provided,* That the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: *Provided further,* That it will be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight with a view to their practical solution, and to determine the problems which should be experimentally attacked and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories either in whole or in part being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories: *And provided further,* That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.

Sec. 2. That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and necessary expenses of members of the committee in going to, returning from, and while attending meetings of the committee: *Provided,* That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.

5. Franklin D. Roosevelt to L. P. Padgett, 12 Feb. 1915, in House Committee on Naval Affairs, National Advisory Committee for Aeronautics, H. Rpt. 1423 to accompany H. J. Res. 413, 63/3, 19 Feb. 1915, pp. 2–3.

[As acting secretary of the navy, Roosevelt was requested to comment on a joint resolution to create an advisory committee for aeronautics. Roosevelt endorsed the proposal, defended the navy's record in aeronautical research, and (most importantly) suggested adjusting committee membership so that government members would outnumber those from private life. This Progressive approach became a permanent part of the NACA canon.]

NAVY DEPARTMENT,
Washington, February 12, 1915.

DEAR MR. PADGETT: I have received House joint resolution 413, of February 1, 1915, to authorize the appointment of an advisory committee for aeronautics, which was forwarded to me by you, for the views of the department.

I heartily indorse the principle upon which this joint resolution to authorize an advisory committee for aeronautics is based. This new method of transportation by air craft will in my opinon soon be utilized commercially as well as in the defense of our country. The great military necessity that has brought such rapid development of air craft about in Europe has demonstrated the practical utility of these vessels of the air, and has placed this country far behind in the use of air craft. Especially are the private engineers and contractors behind in their development of air craft.

This department with the largest "wind tunnel" in the world in operation at the Washington Navy Yard; the model basin at the same place for tests of floats for hydroaeroplanes; the engineering experimental station at Annapolis for tests of machinery; with the aeronautic station and center now in operation at Pensacola, with shops and facilities for all practical tests with actual air craft or the means to provide for them; and with officers studying, experimenting, and training to become aeronautical engineers, has done a great deal to develop the art and the science of aeronautics. However, we will be only too pleased to have an advisory committee that will bring about the cooperation of the private activities and thus greatly increase the effort in attacking the unsolved problems of aeronautics. It is believed that such a committee is the best means required in placing the country on an equality, or even in advance, of other countries in the development of aeronautics.

I have to suggest that in the second paragraph of the aforesaid joint resolution the following be omitted as not pertinent and because it is inaccurate, viz: "but nothing being done by the Government to develop the art and to encourage and assist American inventors and manufacturers beyond the purchase of a few flying machines and the establishment of a small plant at the Washington Navy Yard."

I further suggest that in the fifth line, page 2, of the resolution the word "fourteen" be changed to "ten"; in the fourth line, page 3, the word "seven" be changed to "three"; and in the seventh line, page 3, the word "three" be changed to "one." A committee of 14 seems too large, especially as when this committee is lawfully constituted it can obtain information or advice from all or any sources available without making the advisors a part of the committee. The departments of the Government most interested in the development of aeronautics will be the ones that will be coordinated by the advice of this committee, individually carry out the work required, and be responsible for the expenditures of money appropriated by Congress. Therefore the representatives of the Government should always have the controlling interest in the activities of this proposed committee. The interests of private parties must be more or less commercial and influenced by such considerations. We should guard against even any suspicion that the work of this committee is thus influenced. The above are the important reasons why I recommend the reduced number of members for this proposed advisory committee for aeronautics.

Very truly yours,

FRANKLIN D. ROOSEVELT,
Acting Secretary.

HON. L. P. PADGETT, M.C.,
Chairman Naval Affairs Committee,
House of Representatives, Washington, D.C.

6. Memorandum on a National Advisory Committee for Aeronautics, forwarded by Charles D. Walcott to Senator Benjamin R. Tillman, chairman of the Committee on Naval Affairs, 1 Feb. 1915.

[The excerpt from this memorandum, part of Walcott's personal campaign to establish a national aeronautical laboratory, barely mentions laboratories. Most of the discussion deals with U.S. resources already available in government agencies, and the lead that the European nations had attained over the United States.]

SMITHSONIAN INSTITUTION
Washington

February 1, 1915.

Dear Sir:

I have the honor to acknowledge the receipt of your letter of January 30, 1915, asking for a report showing what action has already been taken by the Smithsonian Institution regarding the Joint Resolution providing for the appointment of an Advisory Committee for Aeronautics in the United States.

In response thereto, I have the honor to submit the inclosed memorandum.

I am transmitting also a report on European Aeronautical Laboratories, which gives an outline of what was being done in Europe prior to the outbreak of the present war.

Very respectfully yours,

(SIGNED) CHARLES D. WALCOTT,
Secretary.

The Honorable Benjamin R. Tillman,
Chairman, Committee on Naval Affairs,
United States Senate,
Washington, D.C.

MEMORANDUM

A NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

HISTORICAL NOTE

On May 1, 1913, the Regents of the Smithsonian Institution authorized Secretary Walcott, with the approval of the Executive Committee, to reopen the Langley Aerodynamical Laboratory; to secure an *Advisory Committee;* to add, as means were provided, other laboratories and agencies; to group them into a bureau organization; and to secure the cooperation with them of the Government and other agencies.

The first action taken by the Secretary was to request the approval of the President of the United States of the designation of representatives from the Departments of War, Navy, Agriculture, and Commerce, to serve on an Advisory Committee. On May 9, 1913, the President approved the request, and the Departments named selected their members for the Committee. A number of civilians were also selected for membership. The Committee was then organized, but before effective work could be undertaken, a decision made by the Comptroller of the Treasury, stated that under Section 9 of the Act approved March 4, 1909 (35 Stat., 1027), it was unlawful for any Government employee to serve on such an Advisory Committee without authority being granted by Congress.

The Board of Regents of the Smithsonian Institution also authorized the Secretary to make an estimate to Congress for the carrying on of operations in such a laboratory. The estimate was made and explained to the Committee on Appropriations of the House of Representatives in January, 1914 (Hearings, Sundry Civil Bill, 63d Congress, 2d Session, pages 419–429). A statement was also made in relation to the desirability of having authority to appoint an Advisory Committee for Aeronautics.

No action was taken by the Committee or by Congress, and the United States remains today the only first class nation in the world that does not have an Advisory Committee or Board on Aeronautics, and one or more aeronautical laboratories devoted to the solution of problems which the manufacturer and practical aviator meet with in connection with the advancement of aerial flight.

America invented and led in the early development of the heavier-than-air flying machine, through Langley, the Wright Brothers, Curtiss, and others, and a small grant was made by Congress to the Navy Department for experimental work in aeronautics, but nothing was done to encourage or assist American inventors and manufacturers, beyond the purchase of a few machines.

European Countries:—As soon as Americans demonstrated the feasibility of flight by heavier-than-air machines, France took the matter up promptly, and utilized all the available agencies, including the army, navy, and similar establishments, both public and private. Large sums were devoted to the research work by wealthy individuals, and rapid advance was made in the art.

Germany quickly followed, and a fund of one million seven hundred thousand dollars was raised by subscription, and experimentation directed by a group of technically trained and experienced men.

Later England established an Advisory Board, placing the manufacturing and the operation of flying machines in the charge of the army and navy, and turning over the working out of the numerous problems arising to the Advisory Board, an annual appropriation of $25,000 being made for expenses and investigations.

Russia also began serious investigations and construction under the Government, and encouraged private enterprise.

When the European war broke out, France had, exclusive of dirigibles, about 1,400 aeroplanes, Germany 1,000, Russia 800, Great Britain 400, the United States 23. The Navy has 12 of these.

ADVISORY COMMITTEE

The Joint Resolution authorizing the appointment of an Advisory Committee for Aeronautics is based on the experience of the Advisory Committee of Great Britain and study given to the subject before asking the appointment of an Advisory Committee for the Langley Aerodynamical Laboratory of the Smithsonian Institution.

The amount of the appropriation asked is not large, but it will be sufficient to test the working possibilities of the Committee, and the results obtained by it will determine if it will be of sufficient value to warrant an increase in the appropriations.

At the present time the United States is proposing to appropriate a million dollars for the Navy, and a large amount for the Army, for the purchase and operation of flying machines, but there is no provision in law authorizing the appointment of an Advisory Committee for Aeronautics, and thus leading to the utilization of all of the resources of the Government and of private laboratories and manufacturing plants, as far as may be, in the development of aviation in America.

The Navy Department will go ahead as best it can; the War Department as it can, and private interests as means and opportunity permit. With no central body or clearing house for the various agencies, no place to meet and discuss problems of research, no place to try out new ideas, and no body of expert advisers for Government and civil interests, aeronautics in America will be simply drifting and trusting to luck that all will come out well through sporadic and scattered efforts. What is needed is team work that may be rendered possible by a wisely selected Advisory Committee.

A national Advisory Committee for Aeronautics cannot fail to be of inestimable service in the development of the art of aviation in America. Such a Committee, to be effective should be permanent, and attract to its membership the most highly trained men in the art of aviation and such technical sciences as are connected with it.

Through the agency of sub-committees, the main Advisory Committee could avail itself of the advice and suggestion of a large number of technical and practical men.

The work for which the British Advisory Committee was appointed was defined in the announcement made by the Prime Minister in the House of Commons on May 5, 1909. . . .*

AGENCIES, RESOURCES, AND FACILITIES AVAILABLE FOR THE WORK OF AN ADVISORY COMMITTEE

Smithsonian Institution.—The Advisory Committee may be provided by the Smithsonian Institution with suitable office headquarters, an administrative and accounting system, library and publication facilities, lecture and assembly rooms, and museum space for aeronautic models. The Langley Aerodynamical Laboratory has an income provided for it not to exceed ten thousand dollars the first year (of which five thousand dollars has been allotted), and five thousand annually for five years.

U.S. Bureau of Standards.—For the exact determination of aerophysical constants, the calibration of instruments, the testing of aeronautic engines, propellers and materials of construction, the cooperation of the Department of Commerce, by the U.S. Bureau of Standards, would be invaluable. This Bureau has a complete equipment for studying the mechanics of materials and structural forms used in aircraft; for standardizing the physical instruments—thermometers, barographs, pressure gauges, etc.—used in air navigation; and for testing the power, efficiency, etc., of aeronautical motors in a current of air representing the natural conditions of flight.

In these general branches the technical staff of the Bureau is prepared to undertake such theoretical and experimental investigations as may come before the Advisory Committee on behalf of either the Government or private individuals or organizations.

U.S. Weather Bureau.—For studies of and reports on every phase of aeronautic meteorology, besides the usual forecasting, the Committee should have the cooperation of the Department of Agriculture, through the U.S. Weather Bureau. This Bureau has an extensive library of works on or allied to aeronautics, an instrument division for every type of apparatus for studying the state of the atmosphere, a whirling table of thirty-foot radius for standardizing anemometers, a complete kite equipment with power reel, and a sounding balloon equipment with electrolytic hydrogen plant, all of which are available for scientific investigations. For special formats, anticipating field tests or cross country voyages, the general service of the Bureau may be called upon.

War and Navy Departments.—These Departments, while specially interested in aeronautics for national defense, can be of service in advancing the general science. Each has an aeronautical library; each has an official representative in foreign countries who reports periodically on every important phase of the art, whether civil or military; each has an assignment of officers who design, test, and operate air craft, and who determine largely the scope and character of their development; each has its aeronautic station equipped with machines in actual service throughout the year. Besides various aviation establishments, the War Department has a balloon plant at Fort Myer, Va., and at Omaha, Neb.; the Navy has its marine Model Basin, useful for special experiments in aeronautics, its extensive shops at the Washington Navy Yard, available for the alteration or repair of air craft, or the manufacture of improved military types, and at Fort Myer, three lofty open-work steel towers suitable for studies in meteorology or aerodynamics in the natural wind. Furthermore, the Navy Department has detailed an officer for special research in aeronautics at one of the principal Engineering Schools.

Because of their fundamental interest in aeronautics, each of these Departments would undoubtedly cooperate most effectively and be able to place at the service of the Committee one or more skilled aviators and aeroplanes for systematic experimentation.

---

*Walcott here quoted from the report excerpted in #1.

Conclusion.—There does not appear to be any good reason why America should not be fully abreast of, if not in advance of, other nations in the development of aeronautics in a practical and useful way, not only for purposes of war but for other activities where great speed in transit through the air, over mountains, bodies of water, or like obstacles, is desirable. If as rapid progress is made in the coming decade as has been made in the past ten years, the flying machine will become as permanent a part of the means of rapid and safe transportation, within certain limitations, as the automobile today is in land transportation.

While it is recognized that an Advisory Committee for Aeronautics will not create or invent new machines, it may be the means of encouraging both Governmental and civil activities in such a manner as to lead to results of great size to the Government and all who are interested in the development of successful aviation as an agency of peace as well as of war.

At the present time, the thought of aviation is in connection with war, but there is no apparent reason why, as in the case of the automobile, the flying machine will not be of far greater service in peaceful pursuits than in war.

7. Brig. Gen. George P. Scriven to Advisory Committee for Aeronautics, 16 April 1915.

[This letter from the first chairman of the NACA, written one week before the first meeting, is a fair picture of early military aviation in the United States. It also demonstrates that, from the outset, the army expected the NACA to serve the purposes of the military, even as far as endorsing military requests for increased appropriations before Congress. Here too is perhaps the germ of the idea of a joint military/NACA research center. The NACA rejected Scriven's final proposal for separating the Committee into three boards, but the Executive Committee wound up as a *de facto* combination of the Administrative Board and Executive Council recommended here.]

April 16, 1915.

To The Advisory Committee for Aeronautics.

In connection with the Act of Congress establishing the Advisory Committee for Aeronautics, I beg to offer the following remarks for the consideration of the Committee.

It appears that the provision of the Act by which the work of the Committee will be guided and limited is mainly covered by the following paragraph of this Act:

"That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions." From this it should seem that the scope of this Committee's work will cover all problems arising in the study and application of the principles of aerial flight; that is, their field of work will include the two great branches of aeronautical science, namely, the theory, construction and consideration of the heavier-than-air machine, now called the aeroplane; and of the lighter-than-air machine—the gas-bag, in any one of its three forms, the dirigible, the free, or the captive balloon.

Without going into details, it is not too much to say that the most important application of aeronautics at the present time is to be found in the use of aircraft in the military land and naval services. But even here radical differences exist, due to varying conditions, and certain wide divergences arise in character and types of machines to be used, which must be carefully studied and worked out by each service for itself in accordance with needs which can only be known by each and must be decided by each. I refer to such differences as naturally arise from flight over land and water, from scouting against troops, and especially those which may arise in the future regarding the dirigible which, however valuable to the Navy, has not yet proved important in land operations.

Whatever may be the developments in the field of aeronautics of the future, and whatever may be the applications of aircraft to the uses of the world in time to come, such as exploration, mail delivery, commercial service, life-saving at sea, and other uses, these developments of the actual field of work have not yet come. Not so regarding their military value and uses, and it therefore appears to me that the immediate problems most requiring attention are those relating to aircraft as military machines which implies the study of aeronautics from the point of view of the National defense, that is the consideration of aircraft as fighting and as reconnaissance machines for service over land and sea. If this aspect of the subject is of first importance, as seems now to be the case, I ask the Committee's attention very briefly to the aeronautics work in progress and proposed by the Signal Corps of the Army, and beg to express the hope that the Naval members of the Committee will also outline something of the work and plans of the naval service in this respect.

In regard to the aeronautical work of the Army I may say that it is now confined to the use of the aeroplane alone. It is not believed that any form of the lighter-than-air machine has yet proved its value in war, and no money has recently been available for the construction of the dirigible for land warfare, even for experimental purposes. Not so the aeroplane—now reckoned as of first importance in the field of information and of which it is said that "the uses of the aeroplane in their order of importance are: first, reconnaissance; second, prevention of the enemy's reconnaissance; third, intercommunication; fourth, observation of artillery fire; fifth, infliction of damage to the enemy."

The plan for aviation work adopted by the Army after a long and, I may say, a hard struggle relates therefore to the use of the aeroplane, hydroaeroplane and flying-boat only as a military machine, to the study of types and character of machines, suitable for military work; to the training of officers and men and to the mechanical auxiliary services needed by aero squadrons at centers and in the field. The plan may be outlined in a few words.

First, the primary object to be attained has been the establishment of a preliminary training school at some point where weather and climatic conditions and terrain are the most favorable for instruction in military flying. In other words, it has been the endeavor first to find that locality at which the beginner may be taught to fly with the greatest of safety to himself and in the shortest time; where he may be instructed in the beginnings of aviation and in the work of the military aviator. Such a school is now established at San Diego, California, where there are now on duty 30 officers and 163 enlisted men, and where there are or shortly will be 22 aeroplanes of the biplane tractor type, and one flying boat. At this school there are excellent though inexpensive buildings, barracks, study and lecture rooms, etc. Flights are made five days of the week, and during 1914, 2680 flights were made, 1397 passengers carried, 824 hours spent in the air, and a total distance of 53,560 miles traveled.* It is believed that the school at San Diego, as established, is doing good work in the training of officers and men in the use of aeroplanes, that is, in training them to become pilots, observers, and mechanicians for use in service with the Army, and in preparing a small carefully selected enlisted force for the military aviation service. This is the first step that has been taken.

The second step in the plan which is being carried out by the military authorities is the establishment of an "Aviation Center"—

---

*Note: During the week ended April 3, 1915, there were 97 flights; 30 hours in the air; 38 passengers carried; and 2,545 miles traveled.

The first: By a center here is meant a higher training school for military aviators, which shall also be a rendezvous and depot, where will be placed an aviation unit called the squadron. The aviation center is intended, as in the English Central School, "to teach the things which make the difference between the mere airman and the military airman, and the course of instruction would include 'progressive flying,' observation, and photography from the air, meteorology, flying by compass, signaling, and (possibly) mechanics and the principles of construction." This squadron as now organized consists of 8 aeroplanes, manned by 8 pilots and 8 observers; with 4 administrative officers in addition, and an enlisted force of 90 men. To the squadron should be added for field service 16 motor trucks for use in transporting spare parts, fuel and other accessories.

The center, it will be understood, should contain a complete and trained unit; the machines be ready for immediate service; and the men who operate them be so experienced and so skillful as to be measurably free from constraint by air currents.

The first aviation center is about to be established at San Antonio, Tex. Here it will be ready for service whenever needed, and will serve and be trained with troops of all arms of service ordinarily stationed at the large garrison of Fort Sam Houston. The center will also form a depot from which detachments of aeroplanes, hydroaeroplanes, etc., may be drawn to supply the needs of the Army in the Philippine Islands, Hawaii, Panama, and in the United States; it will also be drawn upon for service with the Field Artillery and Coast Artillery in their range work, and for all other needed service. Officers and men withdrawn will be recruited from the training school. The buildings for this center are now practically planned and ready for construction, the ground selected, and work is about to begin.

Such are the present plans: One training school at San Diego, Cal., and a first aviation center at San Antonio. Other centers will no doubt be established at various points of the country when needed and when machines and men are available.

At neither the school nor the first center has consideration been given thus far to the dirigible or to the gasbag in any form. No doubt this will come later when money and men are available and perhaps when the present Committee has experimented and made its decision as to the airship, and has decided upon its use as well as upon its limitations. I speak now of its qualities as a carrier.

As to the number and types of aircraft which the Army should acquire at the present time, little need here be said. I personally believe that as a guide it may be considered that a reasonable ratio should be maintained between the size of the Army on one hand and the number of aeroplanes, or dirigibles perhaps, on the other. For when all is said, the air service is but an auxiliary to the Army although an important one, and should therefore be proportioned to its principal, the Army itself; but this auxiliary must be elastic and capable of great expansion in case of necessity. At present I have placed the number of aeroplanes of the first line at four squadrons of 8 aeroplanes* each and 50% for replacements, and two training machines, that is to say, a total of 50 in the first line. In the light of experience, however, and of present information, I now believe these numbers somewhat small even for present needs, and it is growing more and more evident that with the fragile character of the aeroplane, its frequent injury and destruction, and extended and constant use in a great variety of service that there should be provided a much larger number of machines for the first line and its replacements, that is to say, each machine must have one in reserve. But be that as it may, it is a matter in which the Advisory Committee is not greatly interested. On the contrary, however, I believe the Committee is greatly interested with the total

*It seems probable that the size of the air squadron will ere long be increased to 12 aeroplanes, that is, 3 flights of 4 machines each. This is, or was, the English practice.

money cost of aviation, for without monetary assistance liberally given, aeronautics must fall to the ground in this country.

The money appropriated for the use of the Army this year, which is very inadequate, is, all told, but $300,000. A first line of, say, 75 machines in all (23 on hand, 4 squadrons, 100% replacements and, say, 11 training machines), and their maintenance for a year will amount to, say, $750,000 for aeroplane service alone. No account being taken here of the dirigible, even for experimental service. These figures, of course, are very roughly calculated, but they are given with the idea of showing those interested in aeronautics what is considered as the present military needs of the country in this respect, and when the proper time comes will be fully outlined and explained.

It is not meant, of course, that the Advisory Committee has more than a general interest in the actual military requirements of the country, as this is a matter which, of course, must be decided by the Army on the one side and by the Navy on the other. But in regard to money considerations and the general interest of the country and of Congress in aeronautics, the Committee has, I think, a vital interest, and for this and other reasons I am impelled to invite the attention of the Committee to the seriousness of the question of providing sufficient money for this new military branch of service. It cannot be doubted that the views of the Committee officially expressed will have great authority and weight and that such expression will serve to check many of the loose and confusing statements, often entirely erroneous, which appear from time to time in the public prints and have unfortunately found voice in Congress itself.

It appeared clear during several of such discussions of the past winter that each individual has a theory of his own in regard to the value of aeronautics to the country, and as to numbers and kinds of aircraft and amount of money required for this auxiliary. There seemed to be no consensus of opinion regarding the needs of the military, and perhaps, of the naval service. Estimates of the size and cost of aeronautical armament varied largely with the caprice of the speaker; there was no standard recognized, although one existed at the War Department; there was no budget, in spite of official reports; and statements were made of a very injurious character, often as unfair as they were unfounded, regarding the efforts being made to create an air service and concerning the progress of this work. The facts are that a very good beginning had been made, as I know, in the Army, and I believe, in the Navy. Many of the people making these attacks had no appreciation or knowledge of the work done and planned.

Nothing, as it seems to me, will so readily bring order from this chaos as the carefully considered and authoritative decisions of this Advisory Committee, approved and transmitted to Congress by and through proper authority. From their consideration it is to be hoped that it may be found to be within the scope of the Advisory Committee for Aeronautics to receive, and support, recommendations from its military, naval, or civilian members, concerning the needs of each service in this great new field of work in order that this important advisory body may recommend and support with all the authority vested in it the requests for the annual amounts of money asked by the proper authorities of each service for the aeronautical service of the Army, of the Navy, and of other services, with the hope that these recommendations submitted to Congress and having all the force of finality and authority of this Committee shall give a sanction to each department budget that will give Congress a satisfactory ground that shall be standard and beyond cavil.

Such recommendations would of course be confined merely to a repetition of the money requests made by each of the Departments and constitute a kind of aeronautical budget.

I do not venture to offer an opinion as to the legal powers of this Committee to make such a recommendation, simply as to money be it understood, but such action seems both wise and proper.

The point that I desire to bring out is that I believe nothing will better advance the cause of aeronautics in the United States than for this Advisory Committee to recommend and urge with all its authority the appropriations for the Army of such a sum of money (in accordance with its requirements); for other departments so much; for scientific work so much, etc.

I beg to offer one further matter for consideration.

The members of the Advisory Committee are so widely scattered in residence and have no doubt so many diverse interests that it is not probable the Committee as a whole can meet at frequent intervals. I therefore suggest that there be formed, in any way that the Committee sees fit, three working boards. First: An Administrative Board, to be composed of seven members (a majority of the whole Committee), who will give consideration to practical questions of procedure; to methods of encouragement to manufacturers of aeroplanes, dirigibles, and especially to makers of motors; to practical tests and kindred matters; and who shall have authority to act, upon the approval of the entire Committee, as an administrative council for the Committee. The membership of this board might well be made up of the representative of the Smithsonian Institution; the Army and Navy representatives; representatives of the Treasury Department, and of the Agricultural Department.

An Administrative Board thus composed of officers of the Government might well constitute the working board for this Advisory Committee in practical, as distinguished from scientific, matters. The Board being made up of individuals living as a rule in Washington would in general be available at once for duty and ready to meet without added expense. In short, the Administrative Board would be charged with the ordinary conduct of practical affairs of the Advisory Committee. Its decisions and actions would of course be subject to the approval of that Committee as a whole.

A second, or Scientific, Board is suggested to be composed of the remaining five members of the Advisory Committee, gentlemen of the highest scientific standing who, as in the case of the British Advisory Committee for Aeronautics, would be given charge of the scientific and experimental side of aeronautics, the improvements in aerial machines, and their accessories; and of such matters as are mentioned in the English Report of the Advisory Committee for Aeronautics, 1911–12, that is, of general questions in aerodynamics; experiments on airships and aerofoil models, etc.; notes on the resistance of airship shapes; experiments on models of aeroplane wings; the wind resistance of aeroplane struts and an examination of their relative merits; investigation by visual and photographic methods; full-scale experiments; propellers, theory; motors for aeronautical purposes; materials of construction, and fabrics.

It is thought that these two boards will cover the field of endeavor outlined for the Advisory Committee, but for the purpose of practically applying conclusions reached,—a third board, or Executive Council, if it pleases the Committee to so call it, may well be formed.

It is further suggested that this Executive Council be composed of three members selected by the Committee; and that to the Council be given authority to act upon business matters; to outline the scope of work of the other two boards; investigate the subjects to be submitted to them and those that shall be received from outside sources for consideration by the Advisory Committee. The Council might also be given power to authorize the expenditure of funds; audit accounts and to submit reports; in fact, to perform the functions of a board of control, but always subject to the approval of the entire Advisory Committee. These suggestions are only submitted in a general way, without attempt at rigorous definition unnecessary in this place.

In submitting the foregoing remarks to the consideration of the Committee, I remain,

Very respectfully,

George P. Scriven,
Chairman.

8. Josephus Daniels to President Wilson, 30 Nov. 1915.

[Until the NACA was decreed an independent office in 1917, its appropriation appeared as part of the navy budget, as its organic legislation was part of a naval appropriations bill. In this letter, Secretary of the Navy Daniels took exception to the NACA's bid to acquire a laboratory, both because the request would further inflate his own budget and because he considered it contrary to the original plan for the Committee.]

November 30, 1915.

My dear Mr. President:

Last year, as you will remember, Congress appropriated $5,000.00 to cover the expenses of a National Advisory Committee for Aeronautics. Dr. Walcott of the Smithsonian Institute talked to you about it, if my recollection is right, and the appropriation was carried in the Naval Bill.

The Advisory Committee has sent over estimates for next year to the amount of $85,000.00, and requested me to include them this year in the Navy Bill. The increase in our estimates is so large that I hesitate to include them because this Advisory Committee was effected for the development of aviation generally, and not particularly for the Navy. It seems to me they are asking for a very large sum, and that in-as-much as I am asking money for the Naval Consulting Board I ought not to ask for this as well in the Naval Bill. They maintain that this is the only way their appropriation can be obtained. Undoubtedly this Advisory Board can do important work, but it seems to me that when they ask for buildings and equipment they are getting outside of their position as advisors merely, and are beginning a new establishment.

Sincerely yours,

(s) JOSEPHUS DANIELS.

The President,
The White House.

9. Woodrow Wilson to Josephus Daniels, 2 Dec. 1915.

[The president concurs with the thoughts expressed in Document 8. Charles D. Walcott subsequently won the president over to the NACA view.]

The White House,
Washington.

DECEMBER 2, 1915.

My dear Daniels:

I have your letter about the Advisory Committee for Aeronautics and entirely agree with the judgement you there express. I think the committee would make a great mistake in extending its expenses as proposed and might imperil the success of the whole plan of advice.

Cordially and sincerely yours,

(SIGNED) WOODROW WILSON.

Hon. Josephus Daniels,
Secretary of the Navy.

10. Report of the Subcommittee on a Site for Experimental Work and Proving Grounds for Aeronautics, 23 Nov. 1916: excerpt from minutes of Executive Committee meeting, 23 Nov. 1916.

[Charles D. Walcott, Charles F. Marvin, and Samuel W. Stratton had been appointed to recommend a site for the NACA laboratory. They considered such factors as:

"(1) Climate,
(2) Proximity to industry,
(3) Accessibility,
(4) Character of land for experimental flying,
(5) Character of facilities for over water flying,
(6) General locality as affecting attack by enemy from land or water,
(7) General locality as affecting the employment of mechanics,
(8) General locality as affecting the health and well-being of all employees and their families . . . ."

In the end they endorsed the site chosen by the army. Many of the advantages cited by the subcommittee proved to be disappointing.]

Your Committee took advantage of examinations that already had been made under the direction of the Aviation Corps of the War Department, and thus narrowed the search very materially. By a study of topographic maps and the Coast Survey charts, it was soon discovered that there were very few areas that would meet the requirements considered essential by the Committee. By a process of elimination and by personal inspection it was finally decided that the site most nearly meeting all required conditions was situated about 4 miles north of Hampton, Virginia, on the flat lands facing the two branches of Back River, which opens out into Chesapeake Bay. This site is available for purchase at the present time to the extent of 1600 acres or more. It has large areas of cleared land now under cultivation. The removal of a few trees, fences, and a little brush would give a clear field 2 miles or more in length by a half a mile in width. This area could be increased materially by the cutting of a few small groves of trees and brush. There is also available for future purchase several square miles or more of desirable ground.

Most of the area under consideration for a site is about from 4 to 6 feet above mean high tide, and where not naturally well drained, could be drained without undue expense. There are several farm houses and buildings that could be made immediately available for housing quarters, temporary shops, etc.

On the water front there are well-protected and broad inlets. A channel could be readily dredged from the deep water of Chesapeake Bay to a landing station.

The requirements being so fully met by the area north of Hampton, your Committee strongly recommends that this site be secured as soon as practicable.

In view of the general importance of aeronautics in National defense and for the civil activities of the Government and people, it is also the judgment of the Committee that on the site proposed there shall be established a combined experimental and proving ground, affording facilities for all departments of the Government needing them. Such cooperation will lead to a more rapid, sound, and economical development of aeronautics in America.

11. Minutes of the meeting of the NACA Subcommittee on Patents, 10 July 1917.

[Negotiations leading to the cross-licensing agreement of 1917 were rocky and complicated. The meeting reported here was dominated by the issues of membership in the Aircraft Manufacturers Association and inclusion of engines in the agreement. Although government members were virtually unanimous in feeling that engines should be included, the Wright-Martin representatives' views prevailed.]

The committee met in room 518 Munsey Building at 10:30 a.m.

Present:

Dr. W. F. Durand, Acting Chairman,
Dr. S. W. Stratton,
Mr. W. Benton Crisp,
Mr. Sidney D. Waldon,
Rear Admiral D. W. Taylor, U.S.N.,
Professor John F. Hayford,
} Members

Mr. A. H. Flint, Vice-President, Aircraft Manufacturers Association, and President, L.W.F. Engineering Corporation,
Mr. H. B. Mingle, Counsel, Aircraft Manufacturers Association, and President, Standard Aero Corporation,
Mr. George H. Houston, Vice-President and General Manager, Wright-Martin Aircraft Corporation,
Mr. J. P. Tarbox, Counsel, Curtiss Airplane and Motor Corporation,
Mr. F. H. Russell, Manager, Burgess Company,
Mr. Benjamin S. Foss, Assistant Treasurer, B. F. Sturtevant Company,
Mr. Noble Foss, President, Sturtevant Aeroplane Company,
Mr. I. Uppercue, President. Aeromarine Plane and Motor Company,
Mr. F. L. Morse, President, Thomas-Morse Aircraft Corporation,
Mr. C. H. Day, Chief Engineer, Standard Aero Corporation,
Mr. J. H. Harris, Counsel, Aircraft Production Board,
Mr. Benjamin L. Williams, Secretary, Aircraft Manufacturers Association.

The Chairman stated that this meeting had been called to consider the terms of a draft of the proposed cross-license agreement as prepared by Mr. Crisp of the Subcommittee on Patents after consultation with Mr. Fish and the latter's business partner, Mr. Neave, and Messrs. Houston, Tarbox, Flint, and Russell.

Mr. Crisp stated that shortly after the meeting of the Patents Committee on June 18, 1917, he conferred with Mr. Neave, business partner of Mr. Fish, and practically reached an understanding on the main features of the agreement; that then Mr. Houston, Mr. Tarbox, and Mr. Russell were called into conference, the latter sending Mr. Flint in his place; that, as a result of careful deliberation extending over several days, the plan as originally proposed by the committee had been modified in a few important particulars as follows:

First, all reference to engines and engine accessories was omitted for the reason that the principal engine patent—the Hispano-Suiza*—could not be included in the agreement because of the special contract of the Wright-Martin Aircraft Corporation which prevents that, and for the further reason that engine patents in common use in this country were not considered basic.

Second, that after $2,000,000 had been paid to the Wright Company, the subscribers to the agreement would continue to pay $200 per airplane and that payments of the balance then due the Curtiss Company would be made at the rate of $175 per airplane—this with a view of clearing up the situation as quickly as possible.

Third, that the agreement contemplates additional consideration to a party or parties who may develop hereafter an airplane, or engine, or any device of special

*A 220-hp water-cooled French engine manufactured in the U.S. by Wright-Martin Aircraft Corporation.

importance capable of use in an airplane, which would also include: first, a new basic type of airplane; second, one which involves a great improvement on the practices existing in the industry; and third, an airplane radical in its departure from existing types.

Mr. Crisp stated that it is also provided in the agreement that the Government may take from any manufacturer the complete design of an airplane and place it with another manufacturer for production, upon the manufacturer agreeing to pay 1% of the cost of the airplane to the manufacturer from whom the design was taken; that, if the design is placed with a manufacturer not a subscriber to the cross-license agreement, he should pay $200 per airplane to the Aircraft Manufacturers' Association in addition to the 1% of the cost to the other manufacturer.

Mr. Crisp then explained briefly the provisions of each section of the proposed cross-license agreement.

The first matter discussed was the subject of the qualifications for membership in the Association. Mr. Russell read the by-laws of the Association and suggested that they could be amended to provide that any manufacturer who had obtained Government business would be eligible for membership.

Mr. Tarbox moved that the matter of requirements for membership in the Association be referred to a committee of five to be appointed by the Chairman with instructions to make a report this afternoon.

Mr. Houston offered an amendment that the committee be instructed to give careful attention to the legal phases of limitation of stock ownership in a corporation of this nature. This amendment was accepted by Mr. Tarbox.

Mr. Russell stated that the question of limitation of membership is a matter that cannot be handled by a committee in a short time, and that it should receive the very particular attention of the boards of directors of the Wright and Curtiss Companies.

After discussion and on motion duly seconded and carried, it was,

> RESOLVED, that the matter of requirements for membership in the Aircraft Manufacturers Association be referred to a committee of five to be appointed by the Chairman with instructions to make a report this afternoon, and to give careful attention to the legal phases of limitation of stock ownership in a corporation such as the Aircraft Manufacturers Association.

Mr. B. S. Foss raised the question as to who was entitled to vote. After discussion of this question, the Chairman ruled that all present would be entitled to vote.

Mr. Mingle stated that he had been appointed counsel for the Aircraft Manufacturers Association, but that he had not seen a copy of the proposed cross-license agreement until this morning. He suggested that inasmuch as the Association would hold a meeting in Washington tomorrow, Mr Crisp outline the status of the agreement and that this meeting adjourn to allow the Association to consider the proposed agreement.

Mr. Houston stated that the Association should have the general expression of opinion of this body today as to the qualifications for membership, for consideration at its meeting tomorrow.

The Chairman then put the above resolution to a second vote on the understanding that everyone present would be entitled to a vote. After an aye and nay vote, the Chairman announced the resolution was carried unanimously.

Mr. Crisp then suggested that particular paragraphs of the proposed agreement be called up by the members for discussion.

Mr. Noble Foss inquired as to the reason for including propeller hubs and radiators as a part of an airplane, rather than as a part of the engine unit.

Mr. Houston stated that the framers of the agreement had considered the probability that any further developments in radiators or propeller hubs would be along the line of their application to airplanes and propellers, rather than along the line of their application to engines; in other words, by including them as a part of the airplane proper, the subscribers to the cross-license agreement would obtain the benefit of any patented improvements which may come in either of those two factors; and that he believed such patented improvements will come along the line of attachments to planes and attachments to propellers.

Mr. Tarbox stated that the Patent Office classified hubs as a separate invention.

Mr. Russell stated that since there are no basic patents on engines, they had been eliminated from the agreement, particularly because the Wright Company could not cross-license the Hispano-Suiza engine.

In reference to the exclusion of the "Dunne" patents, Mr. Russell stated that the Burgess Company found itself with an exclusive license in very much the same form as the Wright Company had with the Hispano-Suiza Company. He stated that it is the intention of the Burgess Company as soon as possible to place their contract with the holders of the "Dunne" patents in such form as will enable the Burgess Company to cross-license under the "Dunne" patents. He stated that the Burgess Company had a right to cross-license to other manufacturers in this country, but that the 1% license which they were required to pay would exclude, for financial reasons, cross-licensing these patents.

Mr. Crisp inquired if the Burgess Company would enter into a separate agreement that it will by a certain date agree to cross-license, to which Mr. Russell replied that the Burgess Company would endeavor to do this, and would agree to endeavor to do so.

Mr. Houston suggested that the Burgess Company enter into an agreement with other subscribers to the effect that it will cross-license the "Dunne" patents, provided it receives sufficient compensation to meet the terms of its contract with the holders of the "Dunne" patents.*

Mr. Noble Foss inquired if the Hispano-Suiza patents may not be so broad as to be as important and controlling as the airplane patents owned by the Wright and Curtiss Companies. Mr. Tarbox stated that the Hispano-Suiza patents could not be construed as basic; that in order to be basic at this time, a patent would have to embody some new principle of operation, and that it is extremely unlikely that anything basic could be construed to exist in the Hispano-Suiza engine.

Mr. Houston stated that he believed engineers of the Wright Company would in time be able to produce improvements in the Hispano-Suiza engine that would make unnecessary the use of the patents controlling it.

Mr. Uppercue stated it would be a vital mistake not to embody engines in the cross-license agreement, as the engine is the backbone of aeronautic development.

Mr. Tarbox stated that the Curtiss Company would be willing to enter into a cross-license agreement on engines under certain conditions.

Mr. Morse stated that there are three distinct parties in interest in the proposed agreement,—the Government, the Curtiss and Wright Companies, and the Association; that the introduction of the engine into the proposed agreement puts a burden on the manufacturer, inasmuch as the agreement provides for the payment of 1% for the use of another's designs, including engine. He suggested that engines be omitted from the agreement.

Mr. Uppercue stated that in the future the plane manufacturers would in all probability manufacture their own engines, and that, therefore, engines should be included in the agreement.

Mr. Mingle suggested that it might be advisable for the Aircraft Manufacturers Association, as aircraft manufacturers and not as engine manufacturers, to recognize and recommend to its aircraft manufacturing members a cross-license agreement cover-

* J. W. Dunne of England had designed, constructed, and flown a series of tailless swept-wing aircraft for which he claimed unprecedented advances in stability and controllability.

ing airplanes, and making arrangements that the "Company" mentioned in the agreement pay to the Association the surplusses therein set forth, making the aircraft licensing agreement and its "Company" absolutely an outside interest from the aircraft association itself.

Mr. Houston stated that the Wright-Martin Company was not in a position to cross-license the Hispano-Suiza patents, but that it would include in the cross-license agreement such improvements as may be developed by its own organization.

Mr. Tarbox offered the following motion:

> RESOLVED, that it is the sense of this meeting that engines should be included in the terms of the cross-license agreement.

The motion was duly seconded and discussed. The Chairman put the question to an aye and nay vote and announced that the ayes seemed to have it, whereupon a division was called and a rising vote taken. The Chairman announced the result as follows: eight in favor, four opposed. The motion was therefore carried.

Mr. Crisp requested definite action, in addition to the expression of the sense of the meeting, on the question of including engines in the cross-license agreement. Mr. Mingle stated that this matter will be taken up by the Association immediately upon the adjournment of this meeting. The Chairman stated that the Subcommittee on Patents would also consider the matter promptly.

Mr. Harris stated if he and Admiral Taylor could be recognized as speaking for the Government, they would say as a matter of record that the Government desires that engines be included in the agreement.

Admiral Taylor, in referring to paragraph 8, "Payments to the Company," section (a), stated that in his opinion the agreement should provide that in no event should royalties continue to be paid to the Wright Company after the life of its alleged basic patent. At this point, Admiral Taylor and Mr. Harris withdrew.

The question of royalties for repairs and spare parts was discussed.

Mr. Houston stated that at a previous meeting it was agreed that it would be difficult to measure the license to be paid on miscellaneous spare parts and that, therefore, an arbitrary sum should be paid on each airplane as a unit and that the proposed agreement should ignore all spare parts or miscellaneous business done.

Pursuant to previous suggestion of Admiral Taylor, it was recorded as the sense of the meeting that payments to the Wright Company should cease with the life of its patent #821,393 and that payments to the Curtiss Company should run until the expiration of the Curtiss patents, provided that in no event shall the total paid to the Curtiss Company exceed $2,000,000.

The Chairman announced the special committee to consider the question of qualifications for membership in the Association as follows: Messrs. Crisp (Chairman), Harris, Mingle, Russell, and Houston, and the committee was instructed to hold a meeting during the luncheon recess.

Thereupon, at 1 p.m. the Chairman declared a recess until 4 p.m.

The committee reconvened at 4 p.m. Present: Messrs. Durand (Chairman), Crisp, Mingle, Flint, Tarbox, Houston, Russell, Day, Harris, Uppercue, B. S. Foss, Noble Foss, and Fay L. Faurote of the Curtiss Company.

Mr. Crisp, for the committee on qualifications for membership in the Association, submitted the following report:

> A stockholder of this corporation shall be a responsible manufacturer of airplanes, airplane engines, or parts and accessories used in airplanes; a responsible manufacturer who intends to become bona fide producer of airplanes or airplane engines, parts, or accessories; or a manufacturer to whom the Government has given a contract for the construction of ten or more complete airplanes or airplane engines; but no stockholder herein shall acquire or own more than one share of the stock of said corporation.

On motion duly seconded and carried it was,

RESOLVED, that the report of the committee on qualifications for membership in the Aircraft Manufacturers Association be accepted and approved.

Mr. Mingle stated that the Aircraft Manufacturers Association would hold an official meeting tonight to discuss the provisions of the proposed agreement by sections.

The Chairman stated that in an informal way every member of the Subcommittee on Patents who had been present at previous discussions of the patent question had expressed the opinion that engines should be included in the cross-license agreement.

Mr. Houston suggested that the cross-license agreement be re-drafted immediately to include engines so that it could be acted upon by the Association tonight or tomorrow and be ready for approval by the Subcommittee on Patents and the Executive Committee of the National Advisory Committee for Aeronautics by Thursday, July 12.

There being no objection, the Chairman appointed a special committee to re-draft the cross-license agreement, consisting of the following: Messrs. Crisp (Chairman), Tarbox, Houston, Mingle, and Russell.

Thereupon, at 4:30 p.m. the meeting adjourned to meet Thursday, July 12, at 10:45 a.m., to receive a communication from the Aircraft Manufacturers Association.

12. John F. Hayford, "Statement of Policy," 28 April 1917, as adopted by the Executive Committee 7 Aug. 1917, and by the NACA 4 Oct. 1917.

[During his year as chairman of the NACA, Professor John F. Hayford of Northwestern University attempted to instill in the Committee a scientific and academic approach to research. The NACA adopted Hayford's statement of policy, but over the years it adhered to some provisions more closely than to others. Although the Committee devoted considerable attention to data-gathering and comparison of test with free-flight conditions, it rarely subsidized outside researchers in preference to its own staff.]

STATEMENT OF POLICY

(Adopted by the Executive Committee August 7, 1917)
(Approved by the Advisory Committee October 4, 1917)

In supervising and directing "The scientific study of the problems of flight, with a view to their practical solution," the National Advisory Committee for Aeronautics deems it advisable, with a view to securing maximum effectiveness, to carry out the policy indicated in the following paragraphs numbered 1 to 5.

(1) It is of prime importance to secure instrumental records of the facts in regard to airplanes in free flight and to use these records for co-ordinating and testing conclusions from investigations made otherwise. In particular such records should be used:

(a) To determine the extent to which conclusions from separate investigations are modified by the assemblage of parts of an airplane into one organized whole and by the difference between free-flight conditions and the conditions under which the investigations were made.

(b) To select and to formulate the problems which it is important to solve and to obtain an estimate of the relative importance of these problems.

(c) To formulate a true understanding of the conditions of safety in operation, to develop the corresponding indicators and possibly also to determine the best climbing attitude and the economic speed.

(2) The groups of activities which should be fostered in the laboratory which is under the direct supervision of the Committee are in order of their probable relative importance:

(a) Those which contribute to the securing and interpreting of the instrumental records indicated in paragraph (1) or which contribute to the use of such records for the purposes indicated in that paragraph.

(b) Those which serve to suggest or to formulate new laboratory methods of attack on specific aeronautic problems.

(c) Those activities which supplement, in a way which is clearly necessary or desirable, the investigations which have been or are being made elsewhere.

(3) The Committee should endeavor to keep in as close touch as is feasible with all scientific studies of the problems of flight, made anywhere.

(4) The Committee should endeavor to contribute to the success of scientific studies of the problems of flight in laboratories which are independent of the Committee, by direct conference and suggestion, by indicating the probable lines of least resistance to progress, by formulating definite problems and general indications of good methods of attack upon them, and by publishing general reviews or summaries of progress to date.

(5) Whenever a choice is to be made, in attacking a definite research problem, between subsidizing an independent laboratory (or man) and using the Committee laboratory and its regular staff, the Committee will be guided by the relative facilities available, but should in general favor subsidizing, in order to encourage independent research.

13. Lee M. Griffith to Executive Committee, 4 April 1918.

[When Lee Griffith prepared this memorandum, he was an employee of the War Department, detailed to the NACA as an aeronautical mechanical engineer. He rose to senior staff engineer at headquarters before leaving the Committee early in 1920. He returned late in 1922 to become Engineer-in-Charge at Langley Laboratory, only to depart again in 1924 after falling foul of John Victory. This memorandum is the clearest single exposition of the policies and philosophies that were to guide the NACA. Whether Griffith set the tone with this memo, or simply captured the drift of events, is impossible to say. Given the Committee's somewhat erratic course in the early years, the former seems more likely. (The chart mentioned in paragraph three is missing.)]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
MUNSEY BUILDING
WASHINGTON, D.C.

To the Executive Committee,
National Advisory Committee for Aeronautics,
4th & Missouri Ave., Washington, D.C.

As the result of close association with the work of the N.A.C.A. during the past seven months, the writer has had his attention forcibly drawn to certain defects in the present methods of conducting the functions of this Committee. I have come to the service of the Committee from commercial life and have, as a natural result, noted with great misgivings the effort to enlarge our work and influence by means of the prevailing loose and disorganized methods. While I do not wish to appear to pose as an efficiency authority, I do wish to bring to the attention of the Executive Committee some rather definite suggestions and ideas regarding what to my mind are the principal steps to be taken before the N.A.C.A. can be said to be reasonably well organized or prepared to properly fulfill the requirements of the great field which I believe now lies before it.

The following remarks are based on the assurance that the members of this Committee are actuated by the ambition that the N.A.C.A. shall continue to enlarge its value to the nation, and that the goal shall be nothing less than complete recognition as the leading authority and guiding body in the future development of the science of aerial navigation. Especially during times of stress, such as the present, nothing less is to be thought of than the most complete and effective extension of the activities of the Committee to adequately cover its every possible service to our country.

The ordinary commercial enterprise has certain very definite requirements to meet, in order that a reasonable degree of success may reward the effort expended, and these fundamental requirements apply to the governmental body as forcibly as to the purely private enterprise. All are familiar with the fact that the great majority of business failures are the result of failure to observe those laws which would direct the effort in the right direction.

Since the middle of January of this year, the personnel under the direct supervision of the Committee has approximately trebled and the amount of work has increased at a much greater rate. At the present time the force is inadequate to properly handle the immediate work, even at the expense of the almost entire disregard of several fields of usefulness which would seem to naturally come within our scope. On the other hand, I believe that before much further enlargement of the personnel is made, time should be given to the formulation of concrete conceptions regarding the governing requirements which must become our guide in the future, if the Committee is to continue to enlarge its authority and influence in the development of aeronautics.

The ten most important requirements to be observed in the conduct of the activities of the Committee can be briefly stated in the following terms. The order of arrangement is approximately that of their relative importance, at the present time and under the present conditions.

1. A definite statement of intended services.
2. A definite statement of policy.
3. A definite plan of organization.
4. A capable manager having full authority.
5. An organization of known loyalty, skill, and renown.
6. Perfection of product.
7. Energetic and continuous publicity.
8. Efficient and adequate equipment.
9. A suitable location.
10. Definite plans for obtaining sufficient funds.

It should be interesting to take these requirements into consideration, one at a time, and study their application to the conditions involved in the work of this Committee. Being more directly in contact with the details of the work than are the members of the Executive Committee, I may naturally be expected to have a keener appreciation of the difficulties under which the work is being conducted. Therefore, if my remarks seem to be too forceful, I merely ask consideration of the fact that it is desired to bring the ideas prominently to the front.

1. A DEFINITE STATEMENT OF INTENDED SERVICES. It is axiomatic that any enterprise cannot continue to exist unless it is rendering some very definite service to humanity; it must supply some want, whether that want existed previously or not. This service may consist in the supply of materials, manufactured articles, personal services, money, etc. I, together with other members of the personnel, have very hazy ideas regarding the nature of the services that this Committee is endeavoring to render, or is capable of rendering. The act of Congress establishing this Committee

authorized them to "supervise and direct the scientific study of the problems of flight" and "direct and conduct research and experiment in aeronautics." As the most important of our present services we may write down the following:

a. Aid the co-ordination of the aeronautic activities of the several government departments and private interests engaged therein.
b. Conduct research, experimental and development work in the field of aeronautics and intimately related subjects.
c. Collect, collate and distribute scientific, technical, and general information on aeronautic subjects.
d. Examine, test and evaluate ideas and patents relating to aeronautics, and determine their availability for government requirements or for private enterprise.
e. Secure the commercial trial of devices proved valuable by us, and their adoption upon final success.

The field of services under (a) is being invaded only in a very modest way, in spite of the unique position which the Committee occupies as an entirely independent government body and which position distinguishes it as the only aeronautic authority of unquestioned right to arbitrate matters between departments. The renown and authority of the Committee will be greatly increased by the energetic endeavor to have the services of this body utilized to the fullest extent in this field.

It goes without saying that the services enumerated under (b) should be accelerated to the greatest possible extent, consistent with the funds available for both governmental and private sources, since this is the service that can be best rendered by a body of leading scientific men such as constitute this Committee. Up to the present time, the only extensive work in this field has been in the domains of the internal combustion power plant and the screw propeller, and even here, it can hardly be said that the vast problems have been much more than lightly touched upon. The other principal items of airplane research, the aerodynamic problems, have not as yet been even touched by this Committee excepting the propeller applications, although the facilities are being slowly acquired. The large problems connected with the provision of satisfactory aeronautical instruments are being touched upon but lightly, although it is understood to be the intention to carry on this work in an extensive manner in the Committee's laboratory. The broad plans should include provision for the most complete laboratory equipment as well as the most competent personnel which can be obtained for comprehensive research work in all the various branches of the whole subject of aeronautics.

The services under (c) have begun in a modest sort of way and preliminary results are beginning to show the value of this work. Here again, it would seem that the independent position of the Committee should make it the only logical recipient and disburser of aeronautical information. This idea should be persistently fostered, in spite of the opposition likely to be aroused, so that this body may really assume the position of final authority indicated by its very name, National Advisory Committee for Aeronautics.

The service (d) is the only one which is at present in any manner being fully exploited, and even here we are not as yet recognized as constituting the only proper medium for the handling of these matters. Much work remains to be yet done before it becomes fully acknowledged by all other government departments that all aeronautic inventions and ideas are to be referred to this Committee for the determination of their value. Our testing and evaluation functions are at present being exercised in a small way only. Our facilities for this service should be promptly enlarged and the ability of the personnel therein engaged increased.

Under the head of (e) are considered those services which, in the last analysis, determine the ability of the Committee to get its work "across". If the result of all the other classes of service cannot be brought to the point of demonstrable success, the work has largely gone for naught, and the value of the Committee as a force for the advancement of the art will be small indeed. Every effort should be made to get work of known value into active operation.

The thought which should dominate the consideration of the matter under (1) is that some definable statement should be formulated which will cover clearly the whole field of the service of the Committee to all others, as at present conceived. Absolute completeness is not essential even if it were considered possible, since it is readily understood that the opportunities for service will be subject to change from time to time. The idea is that a clear statement at this time will act as a beacon to guide us away from the things which we should not attempt to those which we should accomplish. Until it is known what we are trying to do, it is impossible to formulate any system or build any organization for the doing of that thing.

2. A DEFINITE STATEMENT OF POLICY. This requirement was partly covered by the "Statement of Policy" adopted by the Executive Committee on August 7th, 1917, and by the main Committee on October 4th, 1917. However, the above statement is more properly one of program outline than a general policy. Policy concerns itself only with the broad general principles of action and control.

Perhaps one of the most important items under this head is the determination and recording of the desirable rate of expansion of the services, renown and authority of the Committee. In view of the existing encroachment of other governmental bodies into the fields which may be construed to belong to this Committee, it can hardly be considered that we should do less than perfect our service in all directions at the earliest possible moment. However, a clear understanding of such policy will certainly be an effective stimulant to the work of all.

Other items of policy are contained in the rules for the conduct of the work of the Committee, as given in the pamphlet "Rules and regulations for the conduct of the work of the National Advisory Committee for Aeronautics".

It shall be the policy of this Committee to:

—Exercise all the functions authorized in the Act of Establishment. This should be given a very liberal interpretation, as enumerated partially under (1) above, and should be subject to occasional examination to ensure that no important function is being neglected.

—Formulate definite rules to govern its contact with other government bodies and the methods of making its services available to the same. The same shall be done for private institutions, businesses and individuals, and shall provide for the whole or partial compensation of the expenses incurred by the Committee in conducting the services rendered.

—Expend no funds in the rendering of services which do not promote the art and science, or the industry, of aeronautics as a whole; as distinct from exclusive benefit to individuals or individual enterprises.

—Secure the services of the most competent available men in this country for the guidance of its various technical and scientific activities, as well as for the performance of the same, and to compensate these men in proportion to their value to the work of the Committee.

—Encourage the conduct of associated or independent research and development work by other institutions, corporations and individuals, and to aid in making such work of benefit to all interested in aeronautics.

3. A DEFINITE PLAN OF ORGANIZATION. At the present time the personnel engaged in the activities of the Committee are working without any definite knowledge of the duties which they are expected to perform or of the extent of their individual responsibility to the public or to the Committee, or of the extent of the authority which they are expected to exercise. Obviously, such a condition of uncertainty does not tend

to the development of the maximum interest in the individual duties of the employee or of enthusiastic cooperation in the furtherance of the work of the Committee as a whole. Also, the inevitable overlap or neglect of various specific items of the work are conducive to constant misunderstandings, arguments, and general inefficiency. The net result can hardly be said to benefit the work or contribute to that harmonious cooperation which alone results in the greatest measure of success. The interesting or attractive work is likely to be assumed by more than one person while the duller work is subject to neglect. The lines of responsibility and authority should be sharply defined for each position in the organization. If the plan of organization is to remain permanent, it should connect the positions only and not the individuals who may at any time happen to fill them.

The attached chart of such an organization will serve to disclose the principal relations and positions which appear to the writer to be necessary to provide for a clear and logical mechanism for the conduct of the enlarged services which now lie before the Committee. In this plan of organization, the various branches of our work are clearly separated into the main divisions, considered from a technical standpoint, in order that there may be the least possible necessity for a wide variation of the talent in any main division, or the character of duties performed therein. As the general supervision of the functions and services of the Committee is performed by the acting subcommittees in charge of the various divisions of the work, it is naturally assumed that these subcommittees should be placed at the head of the various organization branches having directly to do with their particular fields of work. This would certainly seem to be an entirely logical arrangement, since the Executive Committee is the instrument through which the National Advisory Committee for Aeronautics carries out its activities, according to the rules and regulations. Naturally the Executive Committee looks to its various subcommittees to actually carry out the specific work in hand, acting, of course, in conjunction with the available facilities of that branch of the organization which is operating on that class of work under consideration.

The two broad divisions into which the organization is divided, under the General Manager, seem to be perfectly natural and logically designated as the Engineering Division and the Administrative Division. The further separation of the Eng. Div. into the various subdivisions enumerated as Aeronautic Eng'g., Mechanical Eng'g., Inventions, and Intelligence, can hardly be considered otherwise than fundamental. The subdivision of the Administrative Division into Secretary, Disbursing, Purchasing, Stenographic and Typing, also seem to be logical. Further subdivisions have been less carefully considered, although the whole plan is the result of considerable thought, and is offered as a basis for the construction of a finished structure which shall be ample to provide for the future growth of the N.A.C.A. to many times its present size. It is by no means intended or expected that all of the positions indicated are to be filled at the present time or in the immediate future, but that in some cases a number of the positions may at the present time be filled by one man. However, as the work increases to such an extent as to be beyond the capacity of any department head to give it adequate attention, the proper subdivision is at once indicated and the duties of the head of the newly occupied position are automatically defined without the slightest reorganization or misunderstanding. This is really one of the most important advantages offered by the adoption of such a definite plan of organization at the earliest possible moment, consistent with a proper consideration of such organization.

4. A CAPABLE MANAGER HAVING FULL AUTHORITY. This is one of the most important requirements to be satisfied, since in no other way than by the establishment of such a position can the activities of the Committee be kept at the highest pitch. Any possible supervision of the work by a committee can hardly be expected to even approximate the degree of effectiveness offered by the provision of a General Manager who is at all times on the job and available to eliminate any difficul-

ties which arise in the prosecution of the work. The Committee cannot be expected to meet oftener than once every week, and this is by no means sufficient to keep the work moving at the most effective speed, even if a committee can be induced to carefully consider the details of the execution of a problem. Committee supervision is most valuable for the initial statement of the problem and the general methods to be adopted in its attempted solution, followed by a general supervision approaching in its nature that of a consulting body, and the final presentation of the results after careful consideration in the form of a report.

One of the chief functions of the General Manager is to at all times represent the ever-present embodiment of the spirit of the Executive Committee in the control of the work and functions. He it is who must be responsible for the uninterrupted prosecution of the various services of the Committee, and the maintenance of the "esprit de corps" which is so necessary to the effective operation of the organization. If the activities of the N.A.C.A. are to continue to enlarge, it becomes increasingly important to have some controlling officer of the Committee always in direct touch with the work and always immediately available for consultation and orders concerning the doubtful or out-of-the-ordinary items of work. This requirement can best be met by the provision of such a General Manager, who shall constitute the routine head of the organization.

The General Manager must be given full authority over the members of the organization, to the same extent as he is empowered in the commercial field, in order that he may be able to do constructive work. Without full authority to add to or diminish the personnel, make minor changes in the practices of the work, etc., he cannot be expected to act as much more than advisor, whose advice can be ignored by a member of the organization with impunity. Of course, his actions are to be guided and controlled by the written policy and regulations of the Committee.

For this post, a man should be selected from the business world who has had extended experience in the handling of people and the upbuilding of organizations. He need not be an engineer or scientist, although such qualifications would not be to his disadvantage. My own idea of the qualifications needed to best fill the position includes those likely to be possessed by a man who has been the main force in building a moderate organization in the engineering mechanical field, where he has been compelled to understand the management of men and the fundamentals of organization building as well as the general engineering problems with which his establishment has had to cope. A man with successful experience in these fields can be safely given the authority and responsibility involved in the position here considered.

5. AN ORGANIZATION OF KNOWN LOYALTY, SKILL AND RENOWN. This is more or less a self-evident condition of success, since it is apparent that the most perfect management can accomplish but little if it is not supported by an organization embodying the above three qualities. While all are somewhat under the control of the management, the first or loyalty is almost entirely so and can be construed as a definite index to the ability of the management to develop the right "esprit de corps". The items of skill and renown are obviously both essential to the final success of our work, and both may be developed to a great extent by proper selection and instruction to secure the skill, followed to a great extent by judicious advertising to spread news of this ability and so add to the renown of the Committee as well as of the individual.

In adding to the personnel, care should be taken to ensure that such new members will bring to the Committee the maximum of experience and ability, and that they are generally respected for their possession of these characteristics. Personnel additions should also show reasonable indication of their ability to work in close cooperation with the rest of the organization as then constituted, as many a man is absolutely impossible from this standpoint although well qualified otherwise.

6. PERFECTION OF PRODUCT. Our product consists largely of reports of the results of our activities in the various services which we are endeavoring to render. While these reports may be valuable contributions to the advancement of the art, their principal usefulness is lost if the advance which they represent is not so utilized as to produce an actual improvement in the practical development of aeronautics. If our light is hid under a bushel, we can not expect it to serve as a beacon for the guidance of the progress of evolution. It makes little difference, whether the field of application for a given improvement, investigation, or research is within the Government or not; if our work is to be of the maximum material value for the advancement of the art, our results must be put in such form and so followed up that their absolute value will be surely demonstrated to all others who are in a position to ensure their utilization.

Under the general subject of reports, it is well to call attention to some of the faults of the ordinary form of such papers, whether they be of scientific or engineering or nontechnical nature. First: they are usually without any specific application which will serve as an adequate illustration of the usefulness and value of the subject matter discussed. This always leaves the user in some doubt regarding the correctness of his method of applying the reported findings to his own problems and may seriously restrict the amount of such application. Also, in the absence of a specific illustration, it may be a difficult matter to convince the reader that the material contained in the report will be of much aid in his specific problems, in which case the value of the work is lost to that extent. All reports of a constructive nature should conclude with as many specific applications as are required to adequately present its value in connection with all of those applications which the subject matter is intended to cover. Where possible, these applications should embody numerical illustrations within ordinary experience.

Second: the logical discussion is ordinarily conspicuous by its absence, and the reader is left to form his own ideas regarding the correctness of the treatment by the author. In case the reader disagrees with the author, he is likely to consider the report as unreliable and of little value, and therefore lose the benefit of the work, when the real differences may be minor. If the discussion had been full and logical, the reader would quickly determine the extent and importance of his disagreement and, making due allowance therefor, still derive much value from the report.

Third: clear and concise summation or conclusions of the results of the work represented by the report. Too often, the reader is compelled to wade through the body of the report in order to ascertain the results gained from the work covered by the report. As the result of this, the report is either neglected and its possible value lost to the prospective user, or incorrect conclusions are derived as the result of inadequate consideration due to the considerable time required for a complete digestion of the matter contained.

Fourth: complete descriptions of the apparatus used in all tests, together with complete statement of the method of conducting such tests and of the detailed data obtained. When the results of such work are finally presented in the form of curves, all of the determining values for the curves should also be shown as there is otherwise considerable uncertainty regarding the correctness of the curve as representing the actual relations obtained. If such determining points are shown, the reader is able to check the curves and to assure himself that they do or do not really represent the relation existing. Also, if the apparatus and methods are completely described, it is impossible to gain a much clearer idea of the reliability of the data and results obtained.

Fifth: standard methods for writing our reports. If all our reports are prepared according to established standards, which will cover all the important points pertaining to such documents, it becomes possible for the writer to do the compiling in a much shorter time and at the same time ensure that each point of his treatment is properly covered. The reader and user of such reports of standardized form will save considerable time by being able to promptly turn to that portion which contains the particular phase in which he happens to be most interested at the time. Thus time is saved at both ends and the information is translated from writer to user with the greatest certainty and accuracy, which is the fundamental requirement of a report.

Standardized forms and instructions for the compiling of reports should be drawn up at once before much of this sort of material has been issued. It is recommended that these standards include complete instructions covering all the following points: Provision of a record sheet which will show the salient facts regarding the history of the report it covers, such as; reason for doing the work leading to the report, description of the work to be performed, whom requested by, benefit expected to result, work actually performed, actual benefits resulting, person in charge of work, author of report, all significant dates, location of tests if any are made, organization or individuals directly benefiting from the work, etc. A log sheet which will show the daily progress of all the matters under investigation or consideration, and providing enough information about each matter so that it will be evident on inspection whether any problems are being in any way neglected. Each report itself should include an adequate treatment in standard sequence of each of the following subdivisions which may be construed to apply to the case in hand: reason for making, whom requested by, scope of actual work, results of work, interpretation of results, theoretical treatment of subject, relation of results to the theory obtaining, summation and conclusions, method of application to practice, illustration of application to concrete modern case, benefits to be obtained, comparison with best previous solutions. The order, method and extent of the treatment of each of the above subdivisions, as well as the determination of the size and other mechanical features of the report, should be completely covered in the form of standardized instructions.

7. ENERGETIC AND CONTINUOUS PUBLICITY. It will hardly be denied that if the work of the N.A.C.A. is to be of the greatest benefit to the advancement of the science of air navigation that knowledge of the Committee and its work should be thoroughly disseminated among all those who are interested in this science, both in this country and abroad. The more prominently this body is known, the easier it becomes to convince others of the value of the work performed, and the easier it is to obtain adequate financial support for the extension of the work. This publicity should take the form of skillful and continuous presentation of the value and extent of the Committee's contributions to this science and to the solutions of the practical problems involved in the practice thereof. This can be obtained through the mediums of the daily press and the technical publications, and should be made as wide as possible. All those of the Committee's reports which are of interest to others engaged in the science or practice of aeronautics should be given such circulation as will ensure that the benefit thereof goes to all those who are able to make use of it. Of course, these broad fundamental considerations are of necessity considerably modified in time of war, but plans should be made to provide for such wide dissemination of the present information after the reason for its suppression is removed.

So important is this matter of publicity for the Committee that the equivalent of a publicity or advertising agent is considered to be a necessary addition to the organization. At the present time, the duties of the position would, however, be combined with other position or positions. A better perspective is obtained if it is considered that this body is fundamentally like a commercial concern in that it is required to sell its product to the public in order to continue its existence. If the public and their representatives in Congress are not properly convinced of the value of this Committee and its work, it certainly cannot be expected that they will provide the money or the legislation needed to enable the Committee to adequately cover the great field of usefulness which is now unfolding before our eyes.

8. EFFICIENT AND ADEQUATE EQUIPMENT. To a large extent, this requirement goes without saying, but certain phases of the matter may well be the subject of consideration. If the technical reports issued by the Committees are to possess the greatest authority, they must be the concrete expression of the results of research conducted on the most perfect class of apparatus, in addition to being the product of men of unquestioned authority. As the membership of this Committee contains so many able scientists, the matter of research, testing, and scientific equipment generally may be lightly passed over in the belief that it certainly will not be neglected.

There is, however, another class of equipment about which there is considerable uncertainty. A portion of the scientific apparatus required is specially designed and built for the special requirements of a problem, or is of such a special character that it is not built by constructors of scientific apparatus except on special order. As the laboratory equipment of the Committee necessarily contains some machine tool equipment, provided primarily to handle the numerous repair and alteration jobs which are always present in connection with many of the problems which are to be handled, there is a strong temptation to enlarge this machine tool investment to undue proportions in the mistaken idea that the laboratory machine shop should or could make the principal items of special apparatus better or cheaper than they can be obtained from outside sources. The added equipment necessitated by such a program is very considerable, since many tools represent a dead or nonworking investment, which can be much better used in financing actual research. In order for the Committee to be able to compete in quality or cost with builders of high-grade apparatus, it is necessary to not only spend much capital to install machinery which will be idle the most of the time, but an organization of skilled men has to be built up and maintained, proper supervision provided and an adequate cost system installed to determine the truth as to whether the laboratory shop is actually building its apparatus as cheaply as it can be obtained in like quality outside. For the amount of such construction at present contemplated, the required machinery, organization and system could hardly be expected to be in good working order by the time the construction jobs would be finished. However, if the volume of such special apparatus building is likely to be considerable, say $10,000 per month minimum, it would probably be desirable to add considerably to the present equipment and take the indicated steps. While the highgrade machine shops of the country are at times so crowded with work as to make prompt deliveries difficult, it is always quite possible to get reasonable deliveries by doing some searching among the lesser known shops, even in times like the present.

The primary business of the laboratory is to conduct research and not to build machine-shop products, therefore it would seem to be self-evident that the less of the latter is undertaken the better for the real purposes of the Committee.

9. A SUITABLE LOCATION. Owing to the conditions surrounding the present location of the laboratory, which render it entirely unsuited for the general offices, it is desirable to limit the personnel at the laboratory to that required for the laboratory operations alone. If this is done, the Langley Field location is reasonably well suited for those laboratory operations which are to be directly conducted by the Committee on its own apparatus. The free-flight and engine-test work in particular call for just such a location as is provided by Langley.

As it is necessary that the Administration and Engineering offices be located in an easily accessible location for the convenience of those who are required to come into personal contact with the Committee, it would seem that these offices can hardly be elsewhere than in Washington, owing to the close connection with other Government bureaus. It is highly desirable, however, that a return to a more central location be effected as soon as possible.

10. DEFINITE PLANS FOR OBTAINING FUNDS. As practically the whole amount of financial support received by this Committee is obtained by Congressional

appropriation, it is obvious that first the public and then Congress has to be convinced of the necessity of such support as is asked. One of the most convincing ways of demonstrating such necessity is to point to advances in the field of aeronautics which are due to the services of the Committee. This has so far been possible only to a very minute extent, which fact has led to much justifiable question of the value of the work of the Committee. Again, it would seem as if appropriations would be easier to obtain if the Committee were better and more widely known; also, if it were known that it was conducting an extensive and carefully planned program of research and investigation, of great value toward the advancement of the science. In particular, members of the appropriations committees of both houses of Congress should be kept cognizant of the accomplishments of the Committee and their effect on advancement.

FINAL. This communication has grown to much greater length than was intended and it is difficult to materially condense. However, it is hoped that its length will not bar it from consideration, as the writer very strongly feels that if the fundamentals herein dealt with are not satisfactorily incorporated into the working machinery of a modern organization, the N.A.C.A. is likely to throw away the present unprecedented opportunity for its growth and service to the country.

It is suggested that the Executive Committee of the N.A.C.A. appoint a special Committee on Organization, to be composed of men who are able to give the requisite time thereto, to consider and formulate the action to be taken along the lines of the broad fundamentals which the writer has endeavored to briefly call to your attention in this letter.

Yours respectfully,

L. M. GRIFFITH,
Senior Staff Engineer.

14. George de Bothezat to Subcommittee on Buildings, Laboratories and Equipments, 15 Feb. 1919.

[From 1918 to 1920 George de Bothezat was the NACA's "Aerodynamical Expert." Like Max Munk, who followed him, he displayed a broader grasp of aeronautics than many of the early NACA staff members, a penchant for research on problems of theoretical interest, an infelicity with the English language, and a disdain for his colleagues—all evident in this letter. All served to undercut his influence within the NACA, though some of his suggestions were adopted over time.]

Gentlemen:

Accordingly to the desire of the Subcommittee———I am presenting herewith a general programme of research work which could be used as general directory at Langley Field. I will allow myself to tell in short words the general ideas that have lead me in the composition of this programme and how I conceive its fulfilling.

From a general standpoint a programme for research must not so much consist in a detailed enumeration of all the questions and problems that can be submitted to research or investigation but rather give the systematization of these problems or questions. That is what I have tried to do in the programme herewith presented. What concerns the detailization of such a programme in each special case it must be left fully to the liberty of those who will undertake these researches, and this is fully necessary for the success of the researches themselves.

Experimental researches or investigations can be of two kinds: Either they simply consist in measurements of some mechanical or physical quantities; Such measurements can be considered as scientific only when they are of a high grade of exactitude; In the other cases they simply constitute routine work. Or the experiments constitute a verification of a general conception of the studied phenomenon. It is the last investigations that generally have the most importance. This kind of conceptional investigations can be undertaken only when they are guided by a deep knowledge of all the studied phenomenon in its whole and its understanding from a unique philosophical standpoint.

What concerns the programs of Messrs. Warner* and DeKlyn,† which I have looked over, they consist merely in an enumeration of different problems that can be investigated but without any systematization of those problems. These papers also contain several theoretical conceptions which in some cases are somewhat doubtful and afterwards contain in some cases suggestions about the results that can be expected; what I think has to be avoided as much as possible in a research programme. So that the papers of Messrs. Warner and DeKlyn look to me more like their own understanding of several aviation problems, than a general program for research and investigation.

The reading of the papers of Messrs. Warner and DeKlyn brings me to say some words about the general spirit that must animate all research in general but special all aerodynamical research, the last being still a very new field of investigation.

Before a general conception of a problem to investigate is stated, one must take account of all the works made before and submit them to a critical investigation. Afterwards in the problem to investigate there must be reached as far as possible a certain general theoretical standpoint and a clear understanding of the connections of the studied problem to other problems and its relation to the general principals of dynamics and hydrodynamics. The last constitutes only the fundamental demand of the continuity of scientifical evolution. The problems studied in aviation do not constitute a fully new science but are only a development of applied dynamics and hydrodynamics and have to be studied only as such.

Thus, as a general conclusion, I will say that before attacking any investigation of a problem we must submit it to a careful study and clearly have in mind all the different opinions expressed about this problem, and not limit ourselves to the pure and simple verification of a very narrow group of ideas.

RESEARCH AND INVESTIGATION PROGRAMME FOR THE WORK AT LANGLEY FIELD

2/15/19.

A.—The study of the different parts of the aeroplane.
B.—The study of the aeroplane as a whole.
A.—The study of the aeroplane parts.
I.—Study of the parts that give lift and drag.
II.—Study of the parts that give drag.
III.—Study of the propeller.
I.—Principal objects aerofoils and rudders.
1.—Study of the laws of steady motion.
a.—Measurement of the values of different coefficients.
b.—Study of the influence of different variations of form on those coefficients.
2.—Study of the flow around aerofoils.
a.—Apparent stream deflection.
b.—Tip vortices.
c.—Fundamental and secondary wave.
d.—Pressure distribution.

---

*Edward P. Warner, chief physicist, NACA Hq.
†John H. DeKlyn, aeronautical engineer, NACA Hq.

3.—Study of the damping phenomenon.
a.—Study of the damping laws.
b.—Measurement of the damping constants.
4.—Study of the laws of hydrodynamical similitude.
a.—Experiments at different speeds.
b.—Experiments with different sizes.
c.—Experiments in different fluids.

Single aerofoils as well as systems of aerofoils have to be studied from all the foregoing standpoints.

II.—The dragging parts.

Study of the different dragging parts of an aeroplane for symmetrical and asymmetrical disposition in the flow and evaluation of the influence of the neighborhood conditions.

III.—Study of the blade screws.

1.—Determination of the best sections to be adopted for blades.
2.—Determination of the best shape to be adopted for blades.
3.—Exact measurements of all the coefficients necessary for blade screws design.
4.—Study of the blades interference on the values of the blades coefficients.
5.—Study of the flow phenomenum around a blade screw.
6.—Study of the blade screw systems.

All this experiment must be conducted taking account of all the new concepts and results scientifically established.

The study of all the foregoing problems must also include the study of all the instruments themselves, which are used for measurements, as the wind tunnels, the different anemometers, etc.

B.—STUDY OF THE AEROPLANE AS A WHOLE.

I.—General characteristics of the aeroplane.

1.—Geometrical characteristics.
2.—Mechanical characteristics.
a.—The weighing of the machine.
b.—Determination of the ellipsoide of inertia of a machine.

II.—The steady motion of the aeroplane.

Measurement of the different forces acting on an aeroplane and study of their laws of variation.

III.—Stability investigation.

1.—Measurement of all the moments and forces acting on an aeroplane in its most general ease of motion.
2.—Study of the different oscillation phenomenon of an aeroplane.

These investigations must not only seek to establish if a given machine is stable or not but must also be directed in the sense to find out the general rules to be used in design by aid of which could be established those dimensions of the aeroplane which can secure complete stability. The study of dirigibility* must be considered as a part of the stability problem.

The Methods

All the foregoing problems can be studied or on models or on full scale objects.

The full scale experiments can be made or in free flight tests or on special railway carriages (more generally special electric cars).

For experiments on models the following methods can be used:

1.—The wind tunnel.
2.—The whirling arm.

*Controllability.

By this method full-scale propellers can also be used.

3.—The method of falling bodies.

This method is susceptible of a considerable development in the case of dropping different bodies from aeroplanes.

4.—The method of gliding models.

Models are brought to glide in a big closed space and their steady motion as well as stability are studied by photographical methods.

5.—The plane radial screw method.

/.See my blade screw investigation/.

The Actually Standing Problems

The problems that are the most important for the development of the actual aviation are the following:

1.—The study of the laws of hydrodynamic similitude to allow to draw exact conclusions from model test.

2.—The study of the blade screws. The modern theoretical investigations of the blade screws have brought that problem to such a state that only a very small amount of measurements have to be performed to reach all the necessary data to design propellers exceedingly satisfying all the practical demands.

3.—The study of stability. We actually possess already much data on the steady motion of aeroplanes that allow a pretty good determination of their performance, but we are far to possess all the necessary data to be able to fully secure the complete stability and maneuverability of an aeroplane. That is why a special attention must he devoted to the last questions.

G. DE BOTHEZAT

15. L. C. Stearns to Joseph S. Ames, 5 April 1919.

[The Office of Aeronautical Intelligence was one of the busiest in NACA headquarters controlling the flow of information that was the NACA's main product. This early scheme of organization and procedure, later refined and amended, gives the flavor of the engineering approach to bureaucratic function and suggests the meticulous attention to detail that became part of the NACA style.]

There is transmitted herewith a statement regarding the Office of Aeronautical Intelligence which contains its authority, its history, and proposed scheme of organization, together with rules for the proper conduct of its affairs.

The submission of further Rules may seem out of place at this time. This is not felt to be the case, however, since previous so-called Rules, owing either to a misconception or lack of experience on my part, were not rules for the efficient functioning of the Office of Aeronautical Intelligence, but merely a statement of the routine to be followed in the conduct of the office details. You will note therefore that under the scheme of organization reference is made to "Routine to Be Followed" for the filing, reproduction, and distribution of reports. These statements of routine work are already familiar to the present existing staff of the Office of Aeronautical Intelligence, a copy being attached hereto.

Your attention is also called to the fact that no provision for a drafting force as such is made for the Office of Aeronautical Intelligence, it being my opinion that all drafting work should be under one section of the Engineering Division of the Committee's Staff. . . .

For the positions of Technical Assistant and manager, I do not care to make any recommendations, but in view of the fact that Mr. C. A. Chayne and myself, who at present function in the above mentioned capacities respectively, desire to give all of our time to work of an aeronautical engineering nature, which requires release from the large amount of routine work necessary to the proper conduction of the Office of Aeronautical Intelligence, it is requested that in forming a permanent organization for the Office of Aeronautical Intelligence we be not considered as candidates for the above respective positions unless our services in those capacities are absolutely necessary.

Respectfully,

L. C. STEARNS
[*Aeronautical Mechanical Engineer.*]

THE OFFICE OF AERONAUTICAL INTELLIGENCE, NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Authority:

The Executive Committee of the National Advisory Committee for Aeronautics in its "Rules and Regulations of the Conduct of the Work of the National Advisory Committee for Aeronautics," approved by the President of the United States, June 14, 1915, with amendments approved by the President up to May 20, 1918; authorized under "Regulations for Conduct of Committee," Article III, paragraph 3, "to collect aeronautical information, and such portion thereof as may be appropriate may be issued as bulletins or in other forms."

Formation:

Under date of January 10, 1918, the Executive Committee placed itself on record as favoring the establishment of an office of aeronautical information under the auspices of the National Advisory Committee for Aeronautics. On February 23, 1918, action was formally taken by the Executive Committee establishing such an office, to be known as the Office of Aeronautical Intelligence.

Some action soon thereafter was taken on the part of the Assistant Secretary of the National Advisory Committee for Aeronautics, looking toward the building up of a working organization; this was shortly turned over, informally, to L. C. Stearns (then Technical Assistant on the Committee's Engineering Staff) under whom the organization progressed until June 6, 1918, when the first Bulletin (No. A. I. 1) was issued, containing a list of reports received by the Office of Aeronautical Intelligence up to June 5, 1918. At that time the personnel of the Office of Aeronautical Intelligence consisted of L. C. Stearns, who supervised the work of the Section and supplied the technical services, and Miss S. C. Nungesser, as index and catalogue clerk.

Under date of June 1, 1918, the Executive Committee instructed Dr. J. S. Ames to investigate the work of the Intelligence office and submit report and recommendations. Accordingly, therefore, rules and regulations for the conduction of the office routine of the Office of Aeronautical Intelligence were drawn up, presented to the Executive Committee under date of June 8, 1918, and approved thereby.

Under date of August 8, 1918, the Intelligence office was placed under the charge of the Editorial Subcommittee by the Executive Committee, which at the same time appointed to membership on the latter subcommittee, Dr. W.C. Sabine, then Director of Scientific and Technical Data for the Bureau of Aircraft Production, War Department.

Under date of September 6, Dr. Sabine was appointed Director of Scientific and Technical Data for the National Advisory Committee for Aeronautics, and placed in charge of the Office of Aeronautical Intelligence, subject to the general control of the Editorial Committee. On November 30, 1918, Dr. Sabine resigned from his membership on the National Advisory Committee for Aeronautics. No action was formally taken relieving him of his office as Director of Scientific and Technical Data, but the control of the Intelligence office in effect reverted to the Editorial Committee. . . .

Under date of February 13, 1919, a set of rules and regulations, revised to fit the then existing peace conditions, was approved by Dr. Joseph S. Ames, as Chairman of the Editorial Committee.

Purpose:

The Office of Aeronautical Intelligence being organized during the war period, was created for the immediate purpose of assisting in the dissemination of technical information relating to aeronautics among the military, naval and certain civil departments of the Government who required such material for the successful conduct of their duties. Under these circumstances the distribution to the industry was not possible except through the military or naval authorities, although it was intended to arrange for such distribution as soon as possible under the circumstances.

After the signing of the armistice, therefore, efforts were made to secure from the military authorities, permission to distribute to the industry the information in the files of the Office of Aeronautical Intelligence. Under date of January 4, 1919, permission was received from the Acting Director of Military Intelligence to distribute "to Aircraft Manufacturers, Designers, etc., in good standing, such technical reports relating to the various phases of research work in aeronautics" as the National Advisory Committee for Aeronautics had received from various sources during the war. This permission expressly prohibited the distribution of "information in reference to military airplanes, including all their equipment and accessories." This has been interpreted, however, to mean only information of a military nature, for obviously a report on an extensive set of tests to determine the proper rib or spar to use on an airplane, though the latter be a military type, is research information.

It being the duty of the Committee to "supervise and direct the scientific study of the problems of flight, with a view to their practical solution," the encouragement of the commercial development of aeronautics is necessary, since through this commercial development and upbuilding of aviation we may arrive most successfully and permanently at the practical solution of the problems of flight. As a further corollary to the above duty we have that of providing for the education of future aeronautical and aerodynamic engineers and specialists through the medium of existing technical educational institutions.

The encouragement of the commerce of aeronautics and engineering and scientific education in aerodynamics and aeronautics can be materially assisted by extensive and well directed dissemination and distribution of technical and research information relating to aeronautics and its scientific progress. It shall be the purpose, therefore, of the Office of Aeronautical Intelligence to collect technical, scientific and research information relating to aeronautics, properly classify it and disseminate the valuable portions thereof to the research educational and industrial institutions engaged in, or associated with aeronautical work.

Organization:

The organization of the Office of Aeronautical Intelligence as contained in the Rules adopted June 8, 1918, was as follows:—

Technical Assistant in charge, L. C. Stearns,

Chief Catalogue and Index Clerk, Miss S. C. Nungesser.

The organization of this office shall hereafter be as follows:—

Manager or Executive

1. Technical Assistant
2. Collaters, or technical employees
3. Principal clerk

a. Index and catalogue clerk

b. File clerks

c. Reproductive clerks

d. Distribution clerks

The authority and responsibilities shall be as follows:—

I. Technical and administrative employees.

1. (a) The manager is authorized to exercise sole and complete control over the execution of policies and activities of the Office of Aeronautical Intelligence, and shall be responsible only to the Editorial Committee (or to the Director of Scientific and Technical Data should one be appointed on the recommendation of the Editorial Committee), who shall determine the policies of the Office of Aeronautical Intelligence, and whose chairman will call only upon the manager for the execution of such orders as may be issued thereby, pertaining to the Office of Aeronautical Intelligence.

(b) All matters such as documents, correspondence, and interviews relating or pertaining to the Office of Aeronautical Intelligence, which may fall into the hands of, or be originated by other members of the Committee's technical, administrative or field staff, shall be called as soon as possible to the attention of the manager who shall, if necessary, call same to the attention of, or take the matter up with the Chairman of the Editorial Committee (or the Director of Scientific and Technical Data).

(c) Notice of all actions pertaining to the Office of Aeronautical Intelligence taken by the Executive Committee or other Subcommittees shall be forwarded as soon as possible (in written form) to the Chairman of the Editorial Committee, a copy going to the manager at the same time.

(d) The file copy of all letters written personally by the Chairman of the Editorial Committee (or Director of Scientific and Technical Data) pertaining to the Office of Aeronautical Intelligence, shall be initialed by the manager before being filed.

2. (a) All requests for reports, receipts for documents, letters transmitting documents and letters of general routine shall be signed by the manager, with suitable title. (Authority was granted L. C. Stearns in letter dated July 11, 1918, to sign "letters transmitting documents . . . . letters or cards acknowledging receipt of documents.") (Under date of December 23, authority was granted L. C. Stearns to similarly transmit reports to bona fide Airplane Manufacturers, in addition to the function of transmitting such documents to government agencies.)

(b) In all correspondence with other Government Departments requiring a formal letter, these letters shall be signed by the Chairman of the Editorial Committee (or Director of Scientific and Technical Data) after being initialed by the manager.

(c) All letters involving the policy of the Office of Aeronautical Intelligence shall be signed by the Chairman of the Editorial Committee (or Director of Scientific and Technical Data) after having been initialed by the manager.

(d) All orders for stenographic work required in the reproduction of reports shall be made out on suitable forms for the Stenographic Department of the Administrative Division of the National Advisory Committee for Aeronautics, and shall be signed by the manager.

(e) All orders for drafting work required in the reproduction of reports shall be made out on suitable forms for the Drafting Department of the Engineering Division of the National Advisory Committee for Aeronautics, and shall be signed by the manager.

(f) All orders for photostat or blueprint work required in the reproduction of reports shall be made out on suitable forms for the proper department (at present this work is done gratis by the Air Service) and shall be signed by the manager.

(g) All reports received which are suitable for reproduction will be so designated by the manager.

(h) All incoming requests for reports shall be approved by the manager.

3. The work of the technical employees of the Office of Aeronautical Intelligence will be directed by the manager, to whom they will be directly responsible for the character and amount of such work as may as be assigned them.

4. All reports reproduced shall be checked at the proper time during the reproductive process, certain of the technical employees being assigned by the manager to this work of checking.

5. The manager may delegate to the technical assistants or to the other assistants such functions as, in the interests of good administration, he deems advisable.

II. Clerical Employees.

1. The principal clerk will direct the work of the clerical employees of the Office of Aeronautical Intelligence, and will be directly responsible therefor to the manager, who will transmit orders to the clerical employees only through the principal clerk.

2. (a) The duties of the index and catalogue clerks will be to suitably index and catalogue all reports and documents received by the Office of Aeronautical Intelligence (see Routine to be Followed in Cataloguing Reports).

(b) One of the index and catalogue clerks shall be designated as being in charge of this phase of the work, to whom the remaining index and catalogue clerks will be responsible, and who in turn will be responsible to the principal clerk for the amount and character of the work assigned to the remaining index and catalogue clerks.

3. (a) The duties of the file clerks will be to prepare and file in suitable receptacles all reports or documents after their indexing by the index and catalogue clerks (see Routine to be Followed in Cataloguing Reports), and to remove therefrom such reports or documents as may be called for by the members of the administrative,, engineering or field Staffs of the National Advisory Committee for Aeronautics.

(b) One of the file clerks will be designated as being in charge of this phase of the work and will be responsible to the principal clerk for the condition and care of the files, as well as the character and amount of work of the remaining file clerks.

4. (a) The duties of the reproduction clerk will be to provide for the proper reproduction of reports. (See Routine for Reproduction of Reports.)

(b) One of the reproduction clerks shall be designated as being in charge of this phase of the work and will be responsible to the principal clerk for the provision, and at the time required, of reports for reproduction, and shall be responsible for the amount and character of the work of the remaining reproduction clerks.

5. (a) The duties of the distribution clerk will be to perform the details required in the distribution of reports. (See Routine for Distribution of Reports.)

(b) One of the distribution clerks shall be designated as being in charge of this phase of the work and shall be responsible to the principal clerk for the proper execution of the details in connection with the distribution of reports, and shall be responsible for the amount and character of the work of the remaining distribution clerks.

Prepared: April 3, 1919.

Approval: The above statement of the formation, purpose and organization of the Office of Aeronautical Intelligence is approved by the Executive Committee, National Advisory Committee for Aeronautics.

Date__________________

Chairman, Executive Committee__________________

OFFICE OF AERONAUTICAL INTELLIGENCE

ROUTINE TO BE FOLLOWED IN CATALOGING REPORTS

I. Assume receipt of a report.

1. Inspected by the technical officer who classifies same by placing upon it the proper file number.

2. An abstract of the report, if necessary, is indicated.

3. Indication is made by underlining (__________) the subjects under which the report should be cross-indexed alphabetically.

II. Report given to Chief Index Clerk.

1. Clerk looks under general file number given to report, and determines the serial number of this particular report (next number after that shown on last shelf card). Clerk then writes card called shelf card (see sample, Fig. 1), which is filed in its proper place immediately upon being made and must not be removed therefrom. This is to prevent duplication of serial numbers and consequent confusion.

2. The serial number of the above shelf card is next written on the report itself (thus 5123.2-*13*) the latter number being the serial number. The date of this indexing is then stamped on report.

This subject is determined by index clerk from number indicated on report by technical officer.	Starters.. (File No.) 3640 Title .... (Serial No.) 24
This is to enable a copy to be requested by author's name.	*Author* (This is to include all identification marks made by author.) *Abstract.* Indicate here if report is placed other than in proper place in general files.

FIG. 1

3. Next a card is made by the Records Clerk for record as follows (see Fig. 2): author or originating source and serial number, if any, is placed first, then title, date catalogued, and complete file number. These are very essential to enable the report to be traced at any time in different ways. These cards serve as chronological record of reports received, and are *not* to be filed when made (as was the case for the shelf card) and those made since date of last casualty list are saved for making next list, after which they may be arranged and filed according to such serial number as they may bear, or if none appears, they are filed chronologically.

4. Cards are then made by Assistant Index Clerk for alphabetical cross-index under subjects indicated by underlining (______). The portions of the title so indicated are to appear as the leading word on the card with the balance of the title properly grouped and following. Vertical lines (so ....) may be used to indicate any portion of title to be omitted in cataloguing.

5. Report itself is placed by Assistant Index Clerk in folder properly numbered to correspond to this number on the report.

6. This is then handed to Files Clerk who files it under its number in the general files. If this is not convenient, a dummy is placed indicating where report may be found. In the case of a report bearing two or more numbers, a dummy is placed in the files under the number not used, which will indicate where the report is filed.

Airplane Engineering Division, Dayton, Ohio	Serial #148
Title 5043.1-7	1/14/19

FIG. 2.

Note:—It is suggested that, when a large number of reports are being indexed at one time, one operation, such as making the shelf cards, be completed on all the reports before passing to another operation. This will serve to add to the efficiency of the work and eliminate confusion.

Date: 1/31/19.

Approved: L. C. Stearns.

OFFICE OF AERONAUTICAL INTELLIGENCE PROCEDURE FOR REPRODUCTION OF REPORTS

I. Assume report in files.

1. The report has been catalogued and casualty list issued in the regular manner.

2. Reports to be reproduced are indicated on the master casualty list which is inspected at regular intervals by the Reproduction Clerk. (Or reproduction may be required by the Distribution Clerk. See Distribution.)

3. Reports indicated as above are secured by the Files Clerk at the request of the Reproduction Clerk. These reports are then prepared by the Reproduction Clerk for reproduction by separating the drawings, photographs, etc., from the typewritten body of the report, work orders being made out for the necessary stenographic or drafting work. These orders are signed by the technical assistant.

4. In the case of photographs or drawings and tables entailing tedious work, requests for photographic or photostatic work are drawn upon the proper department and are to be signed by the Executive.

5. The duplicate of the Work Order or Photostat Order when entered on Work or Photostat Order Record by the Reproduction Clerk is to be *placed in the folder of the report whose number it bears.* This is essential to prevent confusion when the originals of the report seem to be misplaced. When report is returned to its folder, this carbon copy may be removed and the proper entry made in the Work or Photostat Order Record.

II. Assume completion of stenographic or drafting work.

1. Upon completion of work by the stenographic or drafting departments, the material is given to a technical assistant to be checked.

2. Upon completion of the checking, the material is returned to the Reproduction Clerk. If the copies and drawings are to be blueprinted, the number desired being previously noted upon the Work Order by the Technical Assistant, blueprint requests are made out as in the case of photostat orders. *These orders are then entered and treated as in the case of duplicate work orders.*

III. Assume completion of blueprint and photostat work.

1. The prints are assembled into the form of the complete report by a clerk and are then ready for distribution pending which they are filed in their proper folder.

Date: January 31, 1919.

Approved: L. C. Stearns.

OFFICE OF AERONAUTICAL INTELLIGENCE PROCEDURE FOR DISTRIBUTION OF REPORTS

I. Assume reproduction of several copies of report completed.

1. Lists of reports ready for distribution are made up at frequent intervals in the form of a bulletin and sent out to the latest authorized mailing list.

2. A limited number of offices receive the reports indicated on Bulletin as well as copies of the Bulletin.

II. Assume receipt of a request for a report.

1. Request is given to the Executive for approval after which it is given to the Distribution Clerk.

2. If request is approved, the numbers and titles of reports are entered in the distribution record, the Distribution Clerk indicating that this has been done by initialing the order in upper right hand corner.

3. Every effort will be made to fill requests in the order of their receipt and as promptly as possible.

4. The Distribution Clerk will prepare a list of the file numbers of the reports wanted. This list will be handed to the Files Clerk who will collect copies of the reports indicated. *Note.*—Original copies are not to be sent from the office. (See Rules.)

5. If there are not sufficient duplicate copies to meet the Distribution Clerk's request, the Files Clerk should call same to the attention of the Reproduction Clerk who will cause orders to be prepared for reproduction. In case master sheets exist, this will mean that a blueprint order should be prepared for several copies. In case no master sheets have been prepared, work orders for preparing same will be drawn up. (See "Reproduction.")

6. If the required copies of reports are available, they will be sent out accompanied by a letter of transmittal, the date of transmission being entered in the proper column of distribution record. The Distribution Clerk will initial the carbon copy of the transmittal letter when this has been done.

7. The date of the return of receipt is entered in the proper column of the distribution record, the receipt to be initialed as above when entry has been made.

8. If report is to be returned, this date is noted in distribution record and the matter should be promptly followed up and an effort made to have the report returned.

9. When any of the above mentioned records have been initialed as indicated, they are ready to be filed.

Date: 1/31/19

Approved: L. C. Stearns, *Executive.*

16. Research Authorization No. 201, 21 Jan. 1927.

[The research authorizations tell more about the NACA research program than any other single series of documents, not because they necessarily describe what was done at the laboratories but because they explain the what, why, and how of the work the Committee chose to undertake. This—the RA discussed at length in App. F—shows the format used with little alteration throughout the NACA's history.]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH AUTHORIZATION NO. 201

Title: Investigation of Various Methods of Improving Wing Characteristics by Control of the Boundary Layer.

By Langley Memorial Aeronautical Laboratory.

Approved:______, 192-.

Approved: January 21, 1927.

JOSEPH S. AMES,
Chairman, Executive Committee.

Purpose of investigation (Why?) To determine the possibilities of improving wing characteristics by blowing air through transverse slits, as suggested by Professor R. Katzmayr, and by sucking air through transverse slits, as proposed at Gottingen University.

Brief description of method (How?) Tests are to be conducted in the atmospheric wind tunnel on a model airfoil similar to that used by Professor Katzmayr. These tests are to be followed by flight tests on a modified TS airplane.

Wind tunnel tests are to be conducted on the method used at Gottingen University, of sucking air through transverse slits.

Remarks:

Investigation requested by Bureau of Aeronautics, Navy Department, by letter dated December 2, 1926 (No. Aer-M-152-FAM 301-2 QB/HK).

Dates of reports ________________.

Publications ________________.

Copies to: E. G. Reid, J. W. Crowley, Max M. Munk, Engineer-in-Charge. Copy made for E.W.M. 11-1-27. Files (2).

17. Memorandum of the Special Committee on Organization of Governmental Activities in Aeronautics [*11 Feb. 1920*].

[This memo is one of the few written formulations of the division of responsibilities in aeronautics among government agencies. It was prepared as part of the NACA's campaign to establish a bureau of aeronautics within the Department of Commerce. The campaign culminated in the Air Commerce Act of 1926.]

SPECIAL COMMITTEE ON ORGANIZATION OF GOVERNMENTAL ACTIVITIES IN AERONAUTICS

MEMORANDUM

A. Leave to the War and Navy Departments:
 1. Training of pilots, observers, photographers, mechanics, etc.
 2. Authority to establish Reserve Corps of same, etc.
 3. Engineering development.
 4. Procurement of aircraft, etc., after submission for approval to Joint Army and Navy Board (the existing aeronautical board). (In case of the inability of this board to come to a decision upon any question, it may be referred to the National Advisory Committee for Aeronautics.)

B. Agencies, such as the Post Office Department, receiving direct appropriation for aviation purposes, shall control their own procurement, personnel, and operation.

C. The duties of the National Advisory Committee for Aeronautics shall be left as at present.

D. Establish Air Navigation Board under Department of Commerce.
 Membership: Two members each from: War, Navy, Post Office, Treasury, Commerce, Agriculture, and the National Advisory Committee for Aeronautics, appointed by the heads of the organizations.
 Duties: 1. Receive requests for aircraft needs of civil agencies of the Government except those for which Congress makes specific appropriations for aircraft, and make arrangements with the military departments of the Government for detail of the necessary aircraft, personnel, etc.

2. Formulate rules and regulations for interstate civil air navigation, inspection, licenses, etc. Perform the necessary inspection, issue licenses, enforce the regulations, etc. in the name of the Secretary of Commerce.
3. Make plans for air routes, airdromes, landing fields, etc., and in general to carry out wishes of Congress so far as the development of commercial aeronautics by the Government is concerned.
4. Submit annual report for inclusion with annual report of the Secretary of Commerce, reviewing its activities and containing recommendations regarding all branches of its work, including the need of the use of aircraft by the civil agencies of the Government, suggestions for more detailed legislation for the regulation of air navigation, and matters concerning the general development of commercial aviation. Make special reports from time to time when in its judgment circumstances require.

18. "A National Aviation Policy," NACA Annual Report, 1920, pp. 54–56.

[While European nations were promoting commercial aviation by direct subsidy, the NACA recommended that the United States government foster commercial aviation indirectly through research, regulation, and support for aids to flying and navigation. The rationale was to underwrite a healthy industry to form the nucleus of American air power in future wars. This broadly political recommendation, concerned with the entire spectrum of aviation, may be contrasted with the Committee's more narrowly focused statement following World War II (reproduced as document 36).]

A NATIONAL AVIATION POLICY

Aviation activities during the war were concentrated on the development and production of military aircraft. The selection of the landing fields that were established was necessarily guided by military considerations. The close of the war found us with an aeronautic industry at the stage of quantity production, a large amount of aircraft material on hand, a large number of trained flyers, and a few scattered landing fields. In brief, all this constituted the national inheritance from the investment of hundreds of millions of dollars for the hurried development of military aviation during the war. In the two years that have elapsed since the armistice a good proportion of the aircraft material has become obsolete. A majority of the technical personnel and trained flyers have returned to civil life and to pursuits not connected with aviation. The great aircraft industry has almost disappeared, and some of the landing fields have been surrendered. Those that have been retained really represent one of the most valuable physical assets salvaged from our aircraft expenditures.

As a nation we must seek to realize clearly the lessons of the war and to profit by them. Our efforts in the development of a military air force and the organization of an aircraft industry during the war were remarkable accomplishments in themselves, but the handicap of a negligible industry at the outbreak of the war and the general lack of technical knowledge were too great to be satisfactorily overcome in a short time, regardless of the money available. It is now our clear duty to take to heart the lessons and mistakes of the war period and to shape a national aviation policy that will be productive of the greatest possible structural development consistent with prudent economy.

The Government agencies actively concerned with the use of aviation at the present time are the Army Air Service, the Naval Air Service, and the Postal Air Service. Other agencies such as the Geological Survey, the Coast and Geodetic Survey, the Forest Service, etc., have more or less need for the use of aircraft in their work. The National Advisory Committee for Aeronautics is concerned not so much with the promotion of the uses of aviation as with the scientific study of the problems involved and the technical development of the art for the benefit of governmental agencies and of the public generally, but the committee believes that the use of aircraft by the various governmental agencies should be encouraged where its efficient use is practicable; also that the general development of aviation for all purposes should be encouraged by the National Government. The faithful performance of our national duties in these respects becomes compelling from considerations of wise military preparedness.

In time of war aviation will probably be the first arm of offense and defense to come into action. For this there must be an established industry and a trained and active air service. Aerial supremacy at the outset of hostilities would be a tremendous military advantage. Ultimate victory would unquestionably incline to the side that could establish and maintain supremacy in the air. Huge expenditures of money in time of danger and frantic efforts to train personnel and to develop hastily an aircraft industry from almost nothing will not do. There must be wise preparedness; there must be in healthy existence at least a nucleus of an industry capable of adequate expansion; there must exist civil and commercial aeronautical activities in all parts of the country which would be the main support of the industry in time of peace. In pure self-defense the Government must encourage the development of commercial aviation. The alternative proposition is the creation and maintenance of a powerful standing military air service relatively self-reliant in time of war. We cannot, however, afford the expense which such a policy would entail, and there would be no advantage in time of peace from such expenditures comparable in any way to the advantages to be gained from the support of civil aviation. We should maintain an active air service in time of peace which should possess inherent strength and be something more than a mere nucleus for expansion in time of war. In the final analysis, however, we must depend upon civil aviation to furnish a military reserve force. The remarkable accomplishments of our Motor Transport Service during the war were only made possible by the healthy condition of our automobile industry. The problem is to place our aircraft industry in a healthy condition, and to do this we must enter without delay upon a sane, sound policy for the development of civil aviation. The relative cost of fostering an organized plan to develop commercial aviation would be much less than the waste that would inevitably result from unprepared entry into war. Aside from military considerations, the fostering of commercial aviation would in time yield adequate returns in itself in the form of promoting and strengthening our means of transportation, advancing the progress of civilization, and increasing the national wealth.

Aviation is a distinct advance in civilization given to the world by America. The importance of the development of aviation from a military standpoint was not fully appreciated before the war, with the consequent lack of encouragement of the development of the art. The handicap of years of comparative inactivity has not yet been overcome. We cannot afford to repeat the mistakes of the past. We cannot go backward, but must go forward with the intelligent development of aviation in all its branches.

Aviation is still in its infancy; its possibilities, while unknown, appeal to the imagination. The forced development during the war and some of the experimental development since have not been based upon scientific research and sound scientific principles that make for substantial progress. Technical training is necessary, including education in advanced aeronautical engineering; so is the actual training of a large body of men in the technique of the care and operation of aircraft. Broadly speaking, scientific research, technical training, and commercial aviation constitute, or should constitute, the backbone of a national policy.

Reducing to definite form the steps which in the opinion of the National Advisory Committee for Aeronautics are wise and timely, the committee, after careful consideration of all the facts within its knowledge, submits the following specific recommendations:

First. That legislation be enacted providing for Federal regulation of commercial air navigation, licensing of pilots, aircraft, landing fields, etc. At the present time there is no authority of law for any executive agency of the Government to perform such duties. The committee believes that for the executive administration of these new duties of government there should be established in the Department of Commerce a bureau of aeronautics in charge of a commissioner of air navigation, who should also become a member of the National Advisory Committee for Aeronautics. Acting in cooperation with the War, Navy, and Post Office Departments, the committee has prepared a draft of legislation which appears in full in a preceding section of this report under the heading "Organization of Governmental Activities in Aeronautics," and which it strongly recommends for the immediate consideration of Congress. In this connection the committee recommends also the adoption of a policy of Federal aid to the States in the establishment of landing fields for general use in every State in the Union.

Second. That the Congress authorize an American airplane competition in order to stimulate private endeavor in the development of new and improved designs of aircraft, the competition to be under the direction of the National Advisory Committee for Aeronautics, the entries of the successful competitors to be purchased by the Government at a predetermined and announced figure and made available for the use of the Postal Air Service.

Third. That adequate appropriations be made for the military and naval air services in order to permit the continuous development of these exceedingly important arms of the two services, and to enable them to place orders in such a way as to maintain a nucleus of an aircraft industry capable of sufficient expansion to meet military needs in time of emergency. The committee considers this absolutely essential.

Fourth. That the control of naval activities in aeronautics be centralized under a naval bureau of aeronautics in charge of a director of naval aviation. At the present time responsibility for the development of naval aviation is divided between the Office of Operations and the numerous bureaus of the Navy Department. This basis of organization does not permit full cooperation with the Army Air Service or with other governmental and civil agencies nor does it, in the opinion of the committee, promote the efficient development of aviation within the Navy.

Fifth. That the Air Mail Service of the Post Office Department be further extended and developed. This service has given the best demonstration of the practicability of the use of aircraft for civil purposes. It has been seriously handicapped by inability to secure suitable airplanes adapted to its work. The question is one of design, which should be handled by the industry. The remedy lies in the development of the industry, which can only be brought about at an early date by the indorsement and prosecution by the Government of a constructive, comprehensive policy.

Sixth. That the Congress approve the program of scientific research in aeronautics formulated by the committee and provide for the enlarged facilities necessary for its prosecution. Continuous scientific research is necessary for the real advancement of the science of aeronautics. The number and importance of problems requiring solution have increased greatly with the general development of aircraft, and the development of airplanes of all-metal construction will require a large increase in the aerodynamic research and engineering experimentation conducted by the committee at the Langley Memorial Aeronautical Laboratory at Langley Field, Va.

19. Report of the NACA Subcommittee on Federal Regulation of Air Navigation, 9 April 1921, from NACA Annual Report, 1921, pp. 13–15.

[In response to a 1 April 1921 letter from President Warren G. Harding, the NACA prepared this report, which represents its mature judgment on what should be included in civil-aviation legislation. Note that the NACA recommends for itself "in an advisory capacity, the coordination of all aeronautical activities of the Government." Five appendixes expanding on provisions of the basic report have been deleted.]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D.C., April 9, 1921.

The PRESIDENT,
The White House.

DEAR MR. PRESIDENT: In accordance with your letter of April 1, 1921, addressed to Dr. Charles D. Walcott, chairman of the National Advisory Committee for Aeronautics, this committee organized a special subcommittee on Federal regulation of air navigation, as follows:

War Department: Maj. Gen. C. T. Menoher, United States Army; Maj. W. G. Kilner, United States Army.

Navy Department: Rear Admiral D. W. Taylor, United States Navy; Commander Kenneth Whiting, United States Navy.

Post Office Department: Mr. E. C. Zoll, Mr. C. I. Stanton.

Department of Commerce: Dr. S. W. Stratton, Mr. E. T. Chamberlain.

Representatives from civil life: Mr. Sidney Waldon, Mr. F. H. Russell, Mr. Glenn L. Martin.

Dr. Charles D. Walcott, chairman.

Mr. J. F. Victory, secretary.

This subcommittee has taken up, as you directed, the question of Federal regulation of air navigation, air routes to cover the whole United States, and cooperation among the various departments of the Government concerned with aviation, and, in addition, the two questions specified in your letter:

"(*a*) What can and should be done without further legislative action.

"(*b*) What legislative action and appropriations are necessary to carry into effect the recommendations of the subcommittee."

The report of this subcommittee is as follows:

The following general considerations on a national aviation policy are recommended:

1. Aviation is inseparable from the national defense. It is necessary to the success of both the Army and the Navy. Each should have complete control of the character and operations of its own air service.

2. Aeronautics is a comparatively new science capable of such tremendous and rapid development that it is of vital importance, in time of peace, to make the greatest possible progress in the science itself. Everything should be done to stimulate invention and to encourage the practical use of aircraft of all kinds and of all the equipment and appliances necessary or incidental thereto.

3. It is considered impracticable in time of peace to maintain a large armed air force, but it is considered imperative that we maintain a sufficient nucleus of available personnel, including organized reserves, and of adequate equipment of the most modern type as a foundation upon which to build at the outbreak of war.

4. It is essential that commercial aviation be fostered and encouraged in harmony with the military and naval aviation policies and programs. The development of aviation as a whole will be made with the minimum of expense to the Government through

the adoption of a wise and constructive policy for the upbuilding of commercial aviation.

5. The air mail service is an important initial step in the development of civil and commercial aviation. It must be maintained and extended as rapidly as possible, not only to carry the mails but to become a potential war reserve.

6. It is a pressing duty of the Federal Government to regulate air navigation; otherwise independent and conflicting legislation by the various States will be enacted and hamper the development of aviation. For this purpose a bureau of aeronautics should be established in the Department of Commerce. . . .

7. Approved policies with respect to the encouragement and development of commercial aviation should be carried out by the Department of Commerce.

8. The Army Air Service should be continued as a coordinate combatant branch of the Army. Its existing organization should be used in cooperation with the Navy, Post Office, and other governmental agencies in the prompt establishment of national continental airways and in cooperation with the States and municipalities in the establishment of local airdromes, landing fields, and other necessary facilities.

9. The Naval Air Service and the control of naval activities in aeronautics should be centralized in a bureau of aeronautics in the Navy Department.

10. The continuous prosecution of scientific research in aeronautics is now provided for by the National Advisory Committee for Aeronautics, established by law in 1915, and broad questions of policy regarding the coordination of the activities of all governmental agencies concerned with aeronautics should be referred to that committee for consideration and recommendation.

11. The National Committee for Aeronautics should have authority to recommend to the heads of the departments concerned on questions of policy regarding the development of aviation, and to recommend to departmental heads desirable undertakings or developments in the field of aviation. To provide for the more effective discharge of these functions, the chief of the air mail service of the Post Office Department and the chief of the proposed Bureau of Aeronautics in the Department of Commerce should be members of the committee.

12. Under this policy, there would be an Army Air Service under the Secretary of War; a Naval Air Service under the Secretary of the Navy, with its activities centralized in a Bureau of Aeronautics in the Navy Department; an air mail service under the Postmaster General; a bureau of aeronautics for the regulation of air navigation, under the Secretary of Commerce, and for carrying out such policies as may be adopted for the encouragement and upbuilding of civil and commercial aviation; a National Advisory Committee for Aeronautics for the continuous prosecution of scientific research in aeronautics, and, in an advisory capacity, the coordination of all aeronautical activities of the Government.

Referring specifically to the detailed questions under the three headings, namely, (1) "Federal regulation of air navigation," (2) "Air routes to cover the whole United States," (3) "Cooperation among the various departments of the Government concerned with aviation," the committee reports as follows:

1. Federal Regulation of Air Navigation

(*a*) Federal regulation of air navigation can not be accomplished under existing laws. Smuggling and other illegal uses of aircraft can be prevented in a measure.

(*b*) It is recommended that a bureau of aeronautics be established in the Department of Commerce. . . for the regulation of air navigation and for carrying out such policies as may be adopted for the encouraging and upbuilding of civil and commercial aviation, and that an estimate of $200,000 be submitted for the fiscal year 1922.

2. Air Routes to Cover the Whole United States

(*a*) The Post Office Department is specifically authorized to establish an air route between New York and San Francisco. There is some question as to whether existing laws permit it to establish other routes.

The Army has no specific authority of law to establish air routes, but has charted seven important mail airways as follows:

1. One route from Augusta, Me., to Camp Lewis, Wash.
2. One from Washington, D.C., to San Francisco, Calif.
3. One from Savannah, Ga., to San Diego, Calif.
4. One from Augusta, Me., to Miami, Fla.
5. One from Camp Lewis, Wash., to San Diego, Calif.
6. One from Laredo, Tex., to Fargo, N. Dak.
7. One from Chicago, Ill., to Baton Rouge, La. . . .

(*b*) In order to enable the Army to carry forward its program of air routes to cover the whole United States, it is recommended that an appropriation of $2,000,000 be made available during a period of two years.

Attention is drawn to "Necessary aerological service and estimate of costs." It is recommended that such portions of the appropriations asked for as are necessary to give aerologial service on the approximately 4,000 miles of air mail routes now in commission be made available, and that the funds to cover additional stations along the national continental air routes to cover the whole United States be made available as fast as the need is indicated by the Army and the Post Office Department.

It is recommended that legislation be enacted which will definitely authorize the Post Office Department to establish air mail routes between Chicago, Minneapolis, and St. Paul, and between Chicago and St. Louis, and such other air mail routes as may be determined by the Postmaster General as the need for them arises, taking full advantage, wherever practicable of existing or contemplated airways.

3. Cooperation Among the Various Departments of the Government Concerned with Aviation

(*a*) Cooperation among the air services of the Army, Navy, and Post Office with Coast and Geodetic Survey, Bureau of Fisheries, Coast Guard, Weather Bureau, Geological Survey, and forest patrol service is being carried on with excellent results. . . .

It is recommended that the President direct the National Advisory Committee for Aeronautics to appoint a subcommittee composed of representatives of the War, Navy, Post Office, and Commerce Departments, and two civilians representing the aircraft industry, who shall survey the engineering and production facilities of the aircraft industry and shall recommend a policy calculated to sustain and develop the industry to meet the needs of the Government.

(*b*) Attention is drawn to . . . forest fire patrol. . . . It is recommended that the funds ($217,151) and personnel asked for be made available for the purpose specified.

In summing up this report, permit me to emphasize the immediate need of legislation to provide for—

First. A naval air service under the Secretary of the Navy, with its activities centralized in a bureau of aeronautics in the Navy Department.

Second. A bureau of aeronautics under the Secretary of Commerce for the regulation of air navigation and the encouragement and upbuilding of civil and commercial aviation.

Third. The development of a system of national continental air routes to cover the whole United States and to include the meteorological service essential thereto.

Fourth. The extension of the air mail service.

Fifth. Making the chief of the air mail service and the chief of the proposed bureau of aeronautics of the Department of Commerce members of the National Advisory Committee for Aeronautics.

Respectfully submitted,

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
C. D. WALCOTT, *Chairman.*

20. "Report of Proceedings of Second General Conference between Representatives of Aircraft Manufacturers and Operators and National Advisory Committee for Aeronautics," held at Langley Memorial Aeronautical Laboratory on 24 May 1927, undated.

[The annual industry conferences at Langley Laboratory showed off the Committee's work, brought Langley staff members into contact with colleagues from whom they were otherwise isolated, and gave the aeronautical community an opportunitv to propose research to the NACA. The problems of cowling, streamlining, and low-speed maneuverability raised at this conference all became major NACA research projects.]

The second general conference between representatives of aircraft manufacturers and operators and of the National Advisory Committee for Aeronautics was held on Tuesday, May 24, 1927, at the Committee's research laboratory, known as the Langley Memorial Aeronautical Laboratory, located at Langley Field, Virginia. This conference was attended by representatives of aeronautical trade journals and of educational institutions engaged in the teaching of aeronautical engineering, in addition to the representatives of the industry. The National Advisory Committee for Aeronautics was represented by its Subcommittees on Aerodynamics and Materials for Aircraft and members of its laboratory staff.

The members of the subcommittees and most of the invited guests journeyed by boat from Washington to Old Point Comfort and were conveyed to Langley Field by automobile, while others of the party flew direct to Langley Field and some proceeded by train.

The Washington steamer arrived at Old Point at 6:45 a.m. Breakfast was served at the Sherwood Inn at 7:00 a.m. At 8:00 a.m., the party left Old Point in Army automobiles and arrived at the Officers' Club at Langley Field, at 8:25 a.m.

OPENING SESSION

The opening session was held at 8:30 a.m. in the Officers' Club at Langley Field, Virginia. Dr. Joseph S. Ames, Chairman of the National Advisory Committee for Aeronautics, acted as Chairman of the conference. A list of those present is appended.

Doctor Ames stated that the conference has been called by the National Advisory Committee for Aeronautics upon action of the Executive Committee, and that the primary purpose was to secure a discussion of problems involved in the design and construction of aircraft, with special emphasis upon the problems growing out of the needs of commercial aviation, with a view to the incorporation of such problems into the research programs of the National Advisory Committee for Aeronautics for the ensuing year. Before going into the problems, however, the Chairman stated that he would like to introduce Colonel C. C. Culver, Commanding Officer at Langley Field, to whom the Committee felt very much indebted for his interest and cooperation.

Colonel Culver welcomed the guests, saying that not only the research laboratories but the military authorities at Langley Field felt honored by their presence. . . .

The Chairman thanked Colonel Culver for his warm welcome and interesting address. He stated that a great deal of the success of the Langley Memorial Aeronautical Laboratory depended on the cooperation of the Commanding Officer at Langley Field, and that Colonel Culver had done everything possible in this respect, because of his knowledge and appreciation of the Committee's work.

The Chairman said that before the members of the conference visited the various laboratories he wished them to understand clearly the character and scope of the Committee's activities and the facilities and methods employed.

The Chairman then introduced Mr. H. J. E. Reid, Engineer-in-Charge of the Langley Memorial Aeronautical Laboratory.

Mr. Reid welcomed those attending the conference and said that he was glad of the opportunity of meeting the representatives of the aircraft industry and obtaining from them suggestions as to what further work the Committee could do that would be of assistance to the manufacturers in their work. He announced that after the heads of sections had spoken, an inspection of the laboratories would be made in three groups, to be known as the red, white, and green groups according to the color of tags issued to members of the conference at the time of registration. He stated that those with red tags would be under the direction of Mr. Lewis, those with white tags would be under the direction of Mr. Truscott, and those with green tags would be under the direction of Mr. H. J. E. Reid.

Mr. Reid, Engineer-in-Charge, then introduced Mr. Elliott G. Reid, the engineer in charge of the atmospheric wind tunnel.

Mr. E. G. Reid stated that during the past year his section had been studying three major problems, which consisted of a series of pressure distribution tests on models of wings of the Boeing PW-9, an investigation of spinning in general with particular reference to the rather new problem of flat spinning, or autorotation, and an investigation of airfoil characteristics as affected by control of the boundary layer flow. In the course of his remarks, Mr. E. G. Reid displayed a series of charts relating to the various items. These included charts showing the pressure distribution over the upper and lower wings of the PW-9, a chart showing the autorotational characteristics of different wings and wing sections, and charts showing the effect on the air flow around a wing of sucking in air and discharging air, respectively, through slots in the wing surface.

Mr. George J. Higgins, the engineer in charge of the variable-density wind tunnel, was next introduced and he gave a brief outline of the work being done in that wind tunnel. He stated that tests had been made on British models with three different wing sections and the results correlated with those that had been obtained in England by tests of the same models in an atmospheric tunnel and with a full-sized airplane in flight. He said that tests had also been made on an airship model with different fineness ratios. He exhibited charts showing the effect of "scale" on the R.A.F. 15, 19, and 30 airfoils, and the effect of scale on the drag coefficient of a model of an airship.

Mr. Reid then introduced Mr. Elton W. Miller, the engineer in charge of the Propeller Research Equipment.

Mr. Miller described the Propeller Research Equipment as a large wind tunnel of the Eiffel type, in which a full-sized airplane fuselage may be mounted. He said the purpose is to test full-sized propellers under flight conditions and measure the forces. He stated that the air velocity is 100 miles an hour at the throat and decreases to about 12 miles an hour at the opening to the entrance cone. He exhibited diagrammatic charts of the Propeller Research Equipment and added that it would be operated for the first time to-day.

Mr. George L. Dawson, the engineer in charge of the Instrument Section, was next introduced and stated that the work undertaken by that section consisted mainly of the development of special instruments to be used by the Aerodynamics and Power Plant Divisions in their various investigations. He showed on various charts the optical system used on many of the N.A.C.A. instruments and the principles of the accelerometer and of the pressure-measuring instruments.

Mr. John W. Crowley, Jr., the engineer in charge of the Flight Research Section, described the pressure distribution tests that had been conducted during the past year. He said that there was in progress at the present time an investigation of pressure distribution over the wing and tail surfaces of the PW-9 airplane, the pressure being measured at 250 points over the whole airplane. By charts he showed the accelerations obtained at the center of gravity, the wing tip, and at the tail of a PW-9 Boeing pursuit airplane in a "pull-up"; the pressure distribution on the wings of the PW-9 airplane; and the pressure distribution on the hull and tail surface of the U.S.S. *Los Angeles.*

Mr. Reid then introduced Mr. Thomas Carroll, Chief Test Pilot of the Committee, who is in charge of the Flight Operations Section.

Mr. Carroll gave a brief outline of the work that has been done by the Flight Operations Section during the past year. He said that an investigation had been conducted on the characteristics of airplanes and seaplanes in taking off and landing and also that a study of ground effect had been made.

Mr. Marsden Ware, the engineer in charge of the supercharger development at Langley Field, was next introduced.

Mr. Ware described the N.A.C.A. Roots supercharger and stated that, while it is similar in principle to the Roots supercharger that has been used commercially, it differs in many important respects. He then brought out the points wherein the two types differed, and exhibited charts showing the characteristics of the supercharger and the effects obtained by fitting it to airplane engines.

Mr. W. F. Joachim, the engineer in charge of fuel-injection research, was then introduced and stated that the National Advisory Committee, realizing the importance of the development of aircraft in general and especially the importance of increasing the safety from fire hazard, and also increasing the distance of flight, undertook the study and development of the high-speed oil engine for aircraft in 1920. Since that time considerable progress has been made in the development of this engine and Mr. Joachim outlined briefly the investigations that had been carried on. He further stated that it took four years to perfect the Committee's present spray photography equipment with which high-speed moving pictures are taken of oil sprays at rates up to 4,000 pictures per second.

Mr. Reid then requested all those who had not registered please to do so.

The Chairman announced that Mr. Reid would like to have the names of all those who intended to return by the Cape Charles route, so that reservations could be made. He further added that Mr. Reid had several announcements he wished to make.

Mr. Reid stated that at 4:00 p.m. there was to be a demonstration in the hangar of the Katzmayr effect as applied to a TS airplane and also a flight of a Vought airplane with a cut-out center section. He said that transportation would be furnished by Army cars and by members of the laboratory staff. Mr. Reid invited attention to the programs which had been distributed and asked the cooperation of all in adhering to the schedule.

The members of the conference then stepped outside the Officers' Club and posed for a group photograph, after which they divided into three groups and proceeded on a tour of inspection of the Committee's laboratories, in accordance with the following schedule:

	Red	White	Green
Arrive:			
Atmospheric Wind Tunnel	1 9:45	4 11:20	2 10:25
Variable Density Tunnel	2 10:02	5 11:37	3 10:42
Instruments Section	3 10:20	1 9:45	4 11:00

	Red	White	Green
Power Plant Laboratory	4 10:45	2 10:10	5 11:25
Flight Research Airplanes	5 11:20	3 10:45	1 9:50
Propeller Research Equipment	6 11:55	6 11:55	6 11:55

At 12:30 the members of the conference reassembled in the Officers' Club for a buffet luncheon.

JOINT CONFERENCE

At 1:30 p.m. the conference reconvened in the Officers' Club with Dr. Ames presiding as Chairman.

The Chairman stated that, before beginning the formal proceedings for the afternoon, he would like to announce that Mr. Lewis had telephoned to the Washington office of the Committee to get the latest news in regard to the Italian officer, de Pinedo, who was flying from New York to the Azores, and that the latest word received was that he had been picked up near the Azores. This report was unconfirmed but the press regarded it as authentic.

The Chairman then stated the object of the joint conference, his remarks being substantially as follows:

> The National Advisory Committee for Aeronautics called the meeting primarily for its own benefit, as it is the duty of the Committee to furnish advice to everyone interested in aeronautics and to determine by scientific experiments the information on which this advice is based.
>
> The primary purpose of the conference is to secure a discussion of problems involved in the design and construction of aircraft, with special emphasis upon the problems growing out of the needs of commercial aviation, with a view to the incorporation of such problems into the research programs of the National Advisory Committee for Aeronautics for the ensuing year.
>
> In the past, efforts of the Committee have been concentrated mainly on problems which have arisen in the military services, but, owing to the passage of the Air Commerce Act of 1926 and the consequent growth of commercial aviation, it seems desirable for the Committee to consider also problems relating particularly to civil and commercial aviation. The Committee, therefore, is anxious to have brought to its attention the problems growing out of commercial aviation which its laboratories are equipped to study.
>
> Having visited the laboratories of the Committee and having met the members of its technical staff, those attending this conference probably have in their minds a picture as to what the Committee can do. The Committee stands ready to do anything it can. It is not interested in problems relating to any one particular type of aircraft, it is interested in fundamental problems; but there is no fundamental problem which does not have a practical bearing. The Committee would welcome any suggestions which would guide it in the problems to be undertaken.

The Chairman then stated that he thought it best to call upon a few men individually, because he believed they would be able to start a discussion and to offer suggestions which would be helpful. He first called upon Mr. Frank H. Russell, who represented the Aeronautical Chamber of Commerce.

Mr. Russell stated that the problems of commercial aviation, and the building of airplanes particularly, as distinguished from the problems of military aviation, were coming before the manufacturers of this country with increasing force, and that Doctor Ames's remark that the Committee is ready to assist the industry along this line came as a very welcome one. Mr. Russell said that after an inspection of the laboratories of the Committee he thought the growth over last year was almost phenomenal. He said no one could spend a day at Langley Field and see the work that was being done, meet the engineers, and see the wonderful equipment without going away inspired and enthused.

The Chairmen then called upon Honorable E. P. Warner, Assistant Secretary of the Navy for Aeronautics.

Mr. Warner stated that so far as the relation of the services to the National Advisory Committee for Aeronautics is concerned, he was reminded of a wonder that had often crossed his mind as to how human beings ever existed without electric lights, automobiles, and other conveniences that are now accepted so much as a matter of course. He said it seemed now, after seven or eight years of intensive aeronautical research at Langley Field and elsewhere, difficult to conceive how any use of the airplane or any branch of aeronautical operation or aeronautical engineering could have got along without that research, and obviously difficult to conceive how much poorer would have been our knowledge of the data upon which the progress of aeronautical engineering rests had there been no National Advisory Committee for Aeronautics and no laboratory at Langley Field. He stated that it was well known that the Army and Navy have been receiving constant assistance from the National Advisory Committee and that the services had learned to lean upon the Committee. He added that the services have from time to time been able to give assistance by furnishing equipment on loan. Mr. Warner said that, speaking to some degree on behalf of the services, he could say that the services recognized their interest in the development of commercial aviation, in the strengthening of the industry by the expansion of its commercial market; and as a very important means to the consequent strengthening of the industry, the Navy would be glad to do everything in its power to assist the National Advisory Committee in any work that might appear likely to be useful to that end.

Mr. Warner than stated that, speaking as an individual engineer, who like all the other members of the conference had been interested in visiting the laboratories of the National Advisory Committee, there was one suggestion he would like to renew from last year's meeting. He said at that time the Air Mail routes were just getting under way and that the future of commercial aviation seemed rather uncertain, but that now after an additional year of experience it was quite clear that the carriage of passengers was going to become important as well as the carriage of mail, and he thought a study should be made of some of the factors that bear on the comfort and convenience of the passengers of the airplane, and especially on the question of noise and the means of eliminating those sounds which produce unpleasant effects upon the ears of the occupants of the cabin.

The Chairman then called upon Admiral H. I. Cone, Vice President and Treasurer of the Daniel Guggenheim Fund for the Promotion of Aeronautics.

Admiral Cone stated that, judging from his long experience as an engineer, he believed that there had never been in the history of engineering any branch that depended more on laboratory work, and on the fundamentals of mathematics, physics, and other sciences, than aeronautics. He said that we in this country were particularly fortunate in having available the laboratories of the National Advisory Committee.

He said that members of the industry and all who are interested in commercial aviation could congratulate themselves that there is a body of distinguished scientists, physicists, mathematicians, and engineers like the members of the National Advisory Committee for Aeronautics who give their time and attention to helping in the solution of the problems of aeronautics.

He said that the Guggenheim Fund was anxious to assist in every way possible and was looking for ways to aid in the development of aeronautics. He said he wished to report that when the Guggenheim Fund was first organized, and had no definite ideas as to how to accomplish its purpose, it had been helped more by the National Advisory Committee, and especially by Dr. Lewis, than he could say.

Admiral Cone said that there was probably no one who knew more the difficulties of carrying on the work of an establishment like these laboratories than he himself. He said that such an establishment is hampered at every turn, no matter how eager it may be to respond to requests, by regulations of all kinds, by "red tape" with reference to the expenditure of funds, etc., and that everyone, in dealing with the Committee, should bear this in mind and be patient, being ready to assist in every way, as well as demand of the Committee.

Admiral Cone thanked the Chairman for the privilege of speaking.

The Chairman called upon Mr. T. P. Wright, Chief Engineer of the Curtiss Aeroplane and Motor Company, stating that last year Mr. Wright had given the conference helpful suggestions.

Mr. Wright said that, in connection with the preparation of the rules for the safety competition recently instituted by the Guggenheim Fund, a great deal of study was given to the factors that went into the safety of the airplane and it was found that one of the important requirements was that the airplane must have controllability at low speeds. He suggested that this is the feature along the line of safety which calls for more attention on the part of the Advisory Committee than any other. He pointed out that the Committee is working on this problem in connection with the investigation of slotted wings, and he hoped this would lead to greater knowledge of the effect of slots and of combination of slots with aileron action, which would lead to greater improvement than can be realized now. He added that he hoped the study of controllability at low speeds and at high angles of attack, and the control of the burbling of the wing, would be carried as far as practicable in the next year or two.

The Chairman said that at last year's conference a question was asked by Mr. Charles Ward Hall, of Charles Ward Hall, Incorporated, which led to an investigation taken up by the Committee. He called upon Mr. Hall for further suggestions.

Mr. Hall expressed the opinion that there was one element of investigation which has not been carried as far as it might be, namely, the study of the effect of minute protuberances here and there on an otherwise faired streamline body. He said that such information was important in connection with the use of radial engines.

The Chairman remarked that, in the testing of models in the variable-density tunnel, it is essential to reproduce on the model every point on the full-sized airplane. He said that in an atmospheric wind tunnel such detail is not necessary, but in variable-density, to get results free from the scale effect, it was necessary to use models accurate in every detail.

The Chairman said that the question of sound was a very difficult one, and it was hoped to obtain some information along this line from the operation of the Propeller Research Equipment.

The Chairman said he would now call upon a man who had particular reason to be proud of the product of his factory, Mr. Charles W. Lawrance, President of the Wright Aeronautical Corporation, which built the engine used in the airplane in which Mr. Lindbergh recently crossed the Atlantic.

Mr. Lawrance said he would like to enlarge a little on Mr. Hall's remarks. He said that the question of the cowling of air-cooled engines was one about which very little is known, as can be seen from examination of different kinds of airplanes. He described two entirely different conditions of cowling, and pointed out that no definite knowledge was available of the resistance conditions in the two cases. He said it would be very valuable if in the new large sized tunnel an engine could be equipped with various kinds of cowling and experiments conducted on the effects of the different types.

The Chairman said that the remark had been made that two or three wind tunnels like the Propeller Research Equipment were needed on account of the large number of problems which needed to be solved in such a tunnel. He said that the question of the cowling of the air-cooled engine was one of the first which the Committee had resolved to take up with the new equipment.

The Chairman then called upon Mr. S. M. Fairchild, President of the Fairchild Aviation Corporation.

Mr. Fairchild said that he had made many contacts at this conference, and suggested that it might have been well to have the conference two days. He said that the problem in which he was particularly interested was the use of low-speed propellers and that so far it has not been possible to get very accurate data along this line from flight tests. He pointed out that the new propeller-research equipment would be most valuable in this connection, as tests may be carried on which take into consideration the effects of the fuselage and other factors which are apparently very hard to calculate.

Mr. Fairchild also pointed out the desirability of a study of the resistance of cylinder heads sticking out of the various forms of cowling.

The Chairman next called upon Dr. Karl Arnstein, of the Goodyear-Zeppelin Corporation.

Dr. Arnstein said that those interested in lighter-than-air development had reason to be very grateful to the National Advisory Committee for Aeronautics for the wind tunnel tests of airship models in the high-pressure wind tunnel. He said that the new balance was a marvelous achievement, and would insure greater accuracy. He said that another important development by the Committee was the work being done toward the solution of the high-speed oil engine and remarked that it was unnecessary to say that the development of the oil engine would increase the safety and economy of airship operation.

He said he was greatly impressed by the Propeller Research Equipment and hoped airship tests would be conducted in it with full-sized airship cars.

The Chairman said he would call on the representative of the company responsible for the development of a great deal of aircraft material in this country, Mr. S. K. Colby, a representative of the Aluminum Company of America and president of the American Magnesium Corporation.

Mr. Colby said that the question in which he was particularly interested was that of materials, and that the display he had witnessed that morning was one that he could not completely comprehend. He was impressed particularly with the scope of the laboratory, with the wind tunnel and flight research carried on. He said that if there were two or three such laboratories the answers to the questions of commercial aviation would come a great deal sooner.

He said that the particular detail in which he was interested was magnesium. He said it had been thought the development of this metal would grow rapidly, but it had not grown as rapidly as was expected; that the difficulties would be solved, but had not been solved yet.

The Chairman said that he had called upon a number of the people present whom he happened to know personally and who knew something about the Committee. He then requested that others in the conference suggest fundamental problems for investigation by the Committee.

Mr. R. W. A. Brewer of Pitcairn Aviation, Incorporated, said he was interested in the question Professor Warner had raised, the question of noise, to which he had referred at last year's conference. He said that another thing on which he would like to have information was tied up with the question of cowling, and that was the most suitable way of handling the exhaust in the radial air-cooled engine, whether by ring manifolds, short stacks, or what. He would like to be advised as to some way of handling manifolding not only from the viewpoint of silencing, but of the comfort of the passengers and of the durability of the product itself.

He said he was also interested in the question of materials from which cylinders can be made, and he believed the development of an improved method of cylinder construction would be a great advance in the commercial air-cooled engine at the present time.

Mr. R. H. Upson, of the Aircraft Development Corporation, referred to the great dependence of lighter-than-air design at the present time upon the Committee's laboratories at Langley Field. He said that the problem of scale effect, which is a serious one even with heavier-than-air craft, becomes a very dominant problem with lighter-than-air craft, on account of the fact that not only are the scale differences actually so much greater but also the types of full-sized lighter-than-air craft are of such a delicate character that they seem to be peculiarly sensitive to changes in scale. He pointed out that the National Advisory Committee had the only two tunnels in this country, if not in the world, which are suited to the solution of the difficulty of scale effect, particularly with reference to lighter-than-air craft, and that the problems of airship resistance can be studied nowhere else as thoroughly as in either the high-pressure tunnel or the new large tunnel. He said that there were countless problems which might be studied with very good advantage, including the shape, form, and disposition of tail surfaces, and that the investigation of varying fitness ratios had already been started. He said that a thorough study of this problem involves study not only of the various curves for various fineness ratios but of the variations in the curve of results for the same fineness ratio.

The Chairman stated that the British Aeronautical Research Committee has been studying the problem of a suitable design for a wind tunnel similar to this Committee's variable-density tunnel, and had sent to this Committee confidential reports prepared by British scientists on the merits and demerits of our tunnel. He said that the British were skeptical of our tunnel because they were convinced that the character of flow in our tunnel was turbulent, and that a tunnel of the Eiffel type was preferable. The Chairman pointed out, however, that the results obtained by the Committee on models tested in the variable-density wind tunnel checked closely with actual flight tests made in England on full-sized airplanes of the same type, whereas these two sets of results were at variance with the results of tests in the wind tunnel of the National Physical Laboratory on the same models as were tested in the variable-density wind tunnel.

The Chairman further stated that the National Advisory Committee has in mind its responsibility with reference to investigations on lighter-than-air craft.

Dr. Zay Jeffries, of the Aluminum Company of America, pointed out that perhaps the only field in aeronautics in which all aircraft people are interested is that of aerial navigation, which involves the questions of suitable landing facilities, and flight in fogs, snowstorms, bad winds, and other conditions of bad weather. He said that anything the National Advisory Committee for Aeronautics could contribute in this field would be applicable to the whole aircraft industry and would probably hasten the development of commercial aviation. He suggested that someone outline for the conference the status of aerial navigation in bad weather.

The Chairman called upon Dr. L. J. Briggs, of the Bureau of Standards.

Dr. Briggs stated that the experience of the Bureau of Standards had been entirely in the laboratory, in the development of instruments, which, when developed, never meet the full requirements of the flyer. He said he thought it would be much more to the point if someone who had spent long hours in the air under the conditions referred to would recount his experiences, and suggested that Lieutenant Shoemaker be called upon.

Lieutenant Shoemaker said that his experience was limited to operations with the battle fleet in West Indian waters this winter, involving flights of 700 or 800 miles. He said it had been found necessary to abandon the wind-driven earth-inductor compass because it was not dependable, and that an excellent British aperiodic compass had been substituted, which gave magnetic north at all times and was not affected by the turning of the airplane.

Referring to Mr. Lindbergh's New York-to-Paris flight, Lieutenant Shoemaker said he did not understand how he had done it. He described the drift-indicating device used by the round-the-world flyers, and said that in his own experience in seaplane flying he had found that, knowing the force of the wind when he took off and judging its direction from the streaks he could see in the water, he could set his course to allow for the drift. He said that the electrically driven earth-inductor compass and the aperiodic compass were the best instruments now in use to indicate direction, and stated that Mr. M. M. Titterington, of the Pioneer Instrument Company, was thoroughly familiar with these instruments, and also knew what navigation instruments were used by Lindbergh in his flight.

Mr. Titterington said that the problem of air navigation was a very difficult one. He said that it would be possible to fly entirely blind as long as a couple of stars or the sun can be seen, and the fact that long flights have been carried out would seem to show that even with the present equipment this can be done. He said that the problem of taking off and landing in fogs was important.

The Chairman inquired whether any instrument had yet been developed to indicate actual height above the ground as distinct from the indication of pressure of the atmosphere. Mr. Titterington replied that there was promising development along this line, and it was felt that the problem would eventually be solved.

In answer to inquiry as to the instrument equipment carried by Lindbergh, Mr. Titterington said that his instruments were those ordinarily carried by the pilot, and included two small magnetic compasses of the ordinary type, an earth-inductor compass, and a drift indicator, as well as a turn and bank indicator, air-speed indicator, tachometer, and engine instruments of the standard types. He said that Lindbergh had all the instruments that he could readily use, but had no way of reading his position by astronomical observations.

The Chairman remarked that when Alcock and Brown made their transatlantic flight in 1919, he had asked Commander Richardson how they had succeeded in reaching Ireland, and the Commander had replied that they "hit Ireland by the grace of God."

Mr. Fairchild remarked that he had been told when he was in Europe last summer that the British are using an automatic rudder control for directional flying, and that the results obtained were very accurate. He asked whether any information was available on this instrument.

On inquiry of the Chairman, Mr. Lewis said that the Committee had no information regarding this instrument.

Major Leslie MacDill, U.S.A., of the Materiel Division of the Air Corps, after apologizing for introducing the matter at this meeting, called attention to the question of standardization of Army and Navy requirements for aircraft materiel. He said that letters were being sent to the manufacturers asking them what differences between the Army and the Navy requirements caused them difficulty, and which they preferred, and why. He appealed to everyone to give this letter careful consideration and to go into the matter in as much detail as possible, prior to the standardization conference to be held at McCook Field within the next few months.

At this point the Chairman stated that he would turn over the meeting to Dr. George K. Burgess, Chairman of the Committee on Materials for Aircraft of the National Advisory Committee for Aeronautics, for a public session of the Materials Committee.

PUBLIC SESSION, COMMITTEE ON MATERIALS FOR AIRCRAFT

The Committee on Materials for Aircraft then met in joint session with the other members of the conference, Dr. Burgess presiding.

Dr. Burgess announced that the main feature of the meeting would be the presentation of a paper by Dr. E. H. Dix, Jr., of the Aluminum Company of America, on " 'Alclad,' a New Corrosion-Resistant Aluminum Product," but that prior to the presentation of this paper there were one or two items of routine business of the Materials Committee to be taken up. After these were disposed of, Dr. Burgess made a brief statement regarding the importance to aeronautics of the light alloys of aluminum, the chief points he brought out being as follows:

> Aluminum alloys, and especially duralumin, have been studied for a number of years, and attempts have been made to develop an alloy better than duralumin, but have been unsuccessful. The chief difficulty in the use of duralumin is the intercrystalline embrittlement of the material, and there are two problems involved in the study of this embrittlement, namely, that of determining and eliminating the cause of the embrittlement, and that of interposing a protecting layer of material between the duralumin and the atmosphere. In connection with the study of these problems, the cooperation of the producing companies with the government organizations interested has been excellent in all respects. The Aluminum Company has developed an arrangement of metal which is called "Alclad," and which Dr. Dix will describe to the conference.

Dr. Burgess then introduced Dr. Dix.

Dr. Dix presented a detailed discussion of the new product. He said that while, in comparison with steel, aluminum offered high resistance to corrosion, nevertheless the strong alloys, when used in thin sections, required some protection, especially if exposed to mist or salt air. He stated that for the past four years the research laboratories of the Aluminum Company of America had been studying resistance to corrosion, and had developed this new product which consists of a core of 17ST alloy (duralumin) with a surface of pure aluminum.

Dr. Dix exhibited a number of lantern slides showing the internal structure of this material, and submitted a number of samples, which were examined by the members of the conference at the close of the meeting.

Dr. Burgess asked Dr. Jeffries to comment on Dr. Dix's paper.

Dr. Jeffries said it might be interesting to know that the coating of pure aluminum on the surface of the duralumin entailed a slight loss of tensile strength, somewhere in the neighborhood of 5000 pounds per square inch, but it was possible that with further study of the material this could be regained. He said that it was not possible as yet to state definitely what could be expected from this material from the point of view of protection from corrosion. He stated that the Aluminum Company was making every effort to develop this product as a material to be desired by the aircraft industry.

Dr. H. W. Gillett, of the Bureau of Standards, said that from tests at the Bureau of Standards it had been found that pure aluminum was especially resistant to the intercrystalline type of corrosion, and it was expected that tests of the new product at the Bureau would corroborate the belief as to its high resistance to corrosion.

Lieutenant R. S. Barnaby, U.S.N., of the Bureau of Aeronautics, Navy Department, raised the question of the protection of rivets used with the new material. Dr. Dix replied that from tests made by the Aluminum Company it seemed certain that the pure metal would form an electrolytic protection for the rivets.

Dr. Burgess stated that the Committee on Materials for Aircraft was organized with four subcommittees, namely: Metals; Woods and Glues; Coverings, Dopes, and Protective Coatings; and Aircraft Structures. He asked whether any members of the conference had any suggestions to offer relating to the work of these subcommittees.

Mr. B. C. Boulton, Chief Engineer of the Loening Aeronautical Engineering Corporation, said that one thing in which his company was interested, and on which the Army and Navy were not in complete accord, was the question of zinc plating for certain types of tubular structures. He said that there were certain airplane parts which the plating process could not reach but which were subjected to the acid, and he believed it was injurious to attempt to zinc-plate such fittings or parts. He said there was controversy between the Army and the Navy on this point, and he thought the matter would be a suitable subject for further investigation.

Dr. Burgess replied to Mr. Boulton that the Committee would be glad to keep his suggestion in mind.

As there were no further suggestions, Dr. Burgess thanked the members of the conference for their attendance at the meeting of the Materials Committee, and the meeting adjourned.

Following the meeting, the members of the conference made a further inspection of various activities of the laboratory which were of particular interest to them. Demonstrations of the effect of blowing air through transverse slits in the wing, known as the Katzmayr effect, and of a wing with the front portion cut away and equipped with flaps, for improvement in visibility, were conducted at the Committee's hangar and in the air and were witnessed by many members of the conference.

The following were present at the conference:

Members of Subcommittee on Aerodynamics:

Dr. Joseph S. Ames, Johns Hopkins University, Chairman
Dr. L. J. Briggs, Bureau of Standards
Lieutenant W. S. Diehl, U.S.N.
Professor Alexander Klemin, Department of Commerce
Mr. G. W. Lewis, Director of Aeronautical Research, National Advisory Committee for Aeronautics
Major Leslie MacDill, U.S.A.
Professor Charles F. Marvin, U.S. Weather Bureau
Captain H. C. Richardson, U.S.N.
Honorable Edward P. Warner, Assistant Secretary of the Navy for Aeronautics

Members of Subcommittee on Materials for Aircraft:

Dr. George K. Burgess, Bureau of Standards, Chairman
Professor H. L. Whittemore, Bureau of Standards, Vice Chairman and Acting Secretary
Lieutenant R. S. Barnaby, U.S.N.
Mr. S. K. Colby, American Magnesium Corporation
Dr. H. W. Gillett, Bureau of Standards
Dr. Zay Jeffries, Aluminum Company of America
Mr. J. B. Johnson, Materiel Division, Army Air Corps
*Mr. G. W. Lewis, Director of Aeronautical Research, National Advisory Committee for Aeronautics
*Captain H. C. Richardson, U.S.N.
Mr. G. W. Trayer, Forest Products Laboratory
*Honorable Edward P. Warner, Assistant Secretary of the Navy for Aeronautics

Representatives of Manufacturers and Operators:

Aeronautical Chamber of Commerce, New York City:
**Mr. Charles L. Lawrance, Wright Aeronautical Corporation, Paterson, N.J.

*Also member of Subcommittee on Aerodynamics.
**Also representing his own company.

**Mr. F. H. Russell, Curtiss Aeroplane and Motor Company, Garden City, N.Y.
**Mr. S. M. Fairchild, Fairchild Aviation Corporation, New York City
Aircraft Development Corporation, Detroit, Mich.: Mr. R. H. Upson
Allison Engineering Company, Indianapolis, Ind.: Mr. J. S. Bray
Aluminum Company of America, New Kensington, Pa.:
Mr. R. V. Davies
Dr. E. H. Dix, Jr.
Auto Engine Works, St. Paul, Minnesota: Mr. J. D. Mooney
Henry Berliner Company, College Park, Maryland: Mr. Henry Berliner
Boeing Airplane Company, Seattle, Washington: Mr. E. S. Campbell
Curtiss Aeroplane and Motor Company, Garden City, New York:
Mr. F. H. Russell
Mr. T. P. Wright
Mr. W. H. Miller
Mr T. N. Joyce
Mr. M. B. Bleecker
Fairchild Airplane's Manufacturing Corporation, New York City: Mr. S. M. Fairchild
Goodyear Tire and Rubber Company, Incorporated, Akron, Ohio:
Dr. Karl Arnstein
Dr. Wolfgang Klemperer
Charles Ward Hall, Incorporated, New York City: Mr. Charles Ward Hall
Keystone Aircraft Corporation, Bristol, Pa.: Mr. C. T. Porter
Loening Aeronautical Engineering Corporation, New York City: Mr. B. C. Boulton
Glenn L. Martin Company, Cleveland, Ohio:
Mr. C. A. Van Dusen
Mr. L. C. Milburn
Paragon Engineers, Incorporated, Baltimore, Md.: Mr. Spencer Heath
Pioneer Instrument Company, Brooklyn, New York: Mr. M. M. Titterington
Pitcairn Aviation, Incorporated, Philadelphia: Mr. R. W. A. Brewer
Pratt & Whitney Aircraft Company, Hartford, Conn.: Mr. William G. Chamberlain
R. W. Schroeder, Glencoe, Illinois:
Mr. R. W. Schroeder
Mr. John Wentworth
Thomas-Morse Aircraft Corporation, Ithaca, N.Y.: Mr. Raymond Ware
Chance Vought Corporation, Long Island City, N.Y.:
Mr. C. J. McCarthy
Mr. Michael Watter
Wright Aeronautical Corporation, Paterson, N.J.: Mr. Charles L. Lawrance

Representatives of Aeronautical Journals and Educational Institutions:

Aviation, New York City: Mr. W. L. LePage
U.S. Air Services, Washington, D.C.: Mr. Earl N. Findley
University of Michigan, Ann Arbor, Michigan: Mr. Edward A. Stalker

Additional Guests:

Lieutenant Colonel C. C. Culver, U.S.A., Commanding Officer, Langley Field, Va.
Admiral H. I. Cone, The Daniel Guggenheim Fund for the Promotion of Aeronautics
Captain Emory S. Land, U.S.N.
Dr. F. L. Browne, Forest Products Laboratory
Dr. H. L. Dryden, Bureau of Standards
Commander E. L. Gayhart, U.S.N., Washington Navy Yard

Lieutenant Lloyd Harrison, U.S.N., Bureau of Aeronautics
Mr. T. H. Huff
Mr. F. H. Norton, Cambridge, Mass.
Commander E. M. Pace, U.S.N., Bureau of Aeronautics
Mr. H. S. Rawdon, Bureau of Standards
Lieutenant Commander D. Royce, U.S.N., Bureau of Aeronautics
Lieutenant J. M. Shoemaker, U.S.N., Bureau of Aeronautics
Mr. R. H. Smith, Washington Navy Yard
Dr. L. B. Tuckerman, Bureau of Standards
Mr. J. F. Victory, Assistant Secretary of the National Advisory Committee for Aeronautics

Members of Committee's Staff:

Mr. Thomas Carroll, Chief Test Pilot
Mr. Donald G. Coleman
Mr. John W. Crowley, Jr., head of Flight Research Section
Mr. George L. Dawson, head of Instrument Section
Mr. Smith J. DeFrance
Mr. George J. Higgins, head of Variable-Density Wind Tunnel
Mr. Eastman N. Jacobs
Mr. William F. Joachim, head of Fuel-Injection Engine Development
Mr. Elton W. Miller, head of Propeller Research Section
Mr. William C. Morgan
Mr. Elliott G. Reid, head of Atmospheric Wind Tunnel
Mr. Henry J. E. Reid, Engineer-in-Charge
Mr. Walter H. Reiser
Mr. Oscar W. Schey
Mr. Edward R. Sharp, Chief Clerk of Laboratory
Mr. Marsden Ware, head of Power Plants Division
Mr. F. E. Weick

21. Memorandum, George W. Lewis to General [Herbert M.] Lord, director of the Bureau of the Budget, "Some Accomplishments of the National Advisory Committee for Aeronautics," 13 Sept. 1928.

[The NACA always had to justify its activities to laymen in Congress and the executive branch who were unfamiliar with the technology of flight. In this memorandum to the Director of the Bureau of the Budget, George Lewis characteristically emphasized the practical applications of NACA research and the expected savings to the military services and the American aviation industry.]

The activities of the National Advisory Committee for Aeronautics have been concentrated on solving those problems that will increase the safety and reduce the cost of construction and operation of aircraft. The major emphasis has been placed on those fundamental problems dealing with these two important subjects. However, the Committee has been mindful of the immediate requirements of the Army and Navy and those interested in the manufacture and operation of purely commercial type aircraft.

In the past and at present the major portion of the Committee's activities has been in connection with requirements of the Army and Navy to solve immediate problems that will make for safer and more reliable aircraft for military purposes.

To be of maximum service to the industry, the Committee each year calls a conference of the manufacturers and operators of commercial type aircraft, and at this conference the representatives of the industry are invited to present those problems the solution of which, from their experience, will reduce the number of accidents and further reduce the cost of construction and operation of commercial type aircraft.

Aerodynamic Loads on Airplanes. In the development of military aircraft one of the outstanding contributions made by the Committee has been the determination of the aerodynamic loads to which the aircraft is subjected in military maneuvers. The Committee has determined, by the aid of specially designed instruments which exist nowhere else in the world, the actual loads to which the wings, the control surfaces, and other portions of the airplane are subjected in military maneuvers. The information thus obtained has made possible the safe structural design of military aircraft operating at speeds up to 250 miles per hour. The safety factors on which military types of aircraft are now constructed are based on the results obtained in free flight tests, showing the actual measurement of the air loads on the wings and tail surfaces of the airplane.

Aerodynamic Loads on Airships. In connection with the development of airships in the United States, the Committee has been called upon to investigate the air loads on the airship hull and the controls of the U.S.S. *Los Angeles.* This was a gigantic undertaking, involving the construction of new types of instruments for these measurements. The investigation has been completed and report submitted to the Navy Department, and the design of the two new airships for the Navy is largely based on the fundamental information obtained in the flight tests with the *Los Angeles* in steady flight and in air conditions such as are encountered in service operation.

Study of Controllability and Maneuverability. Another important contribution made by the Committee has been the development of a series of instruments that measure the controllability and maneuverability of aircraft. These two characteristics are the determining factors that mark a poor or a good type of airplane for military purposes. Prior to the development by the Committee of means and methods for actually measuring the controllability and maneuverability of airplanes, these characteristics were gauged and measured by the impressions of the pilot. Needless to say, these impressions were often misleading, resulting in the purchase of aircraft not suitable for the purpose intended. This contribution of the Committee will make possible the selection of airplanes with the maneuverability and controllability characteristics desired, and will therefore result in the elimination of the loss of money by the purchase of aircraft not suitably maneuverable and controllable.

Spinning Characteristics of Airplanes. As a result of investigations by the Committee on the problem of the spinning of airplanes, information has been obtained which will make it possible to construct airplanes which will not have undesirable spinning characteristics. Airplanes have been purchased in the past which had a spinning characteristic which was not controllable, and resulted in fatal accidents and the destruction of the airplanes. This has been one of the most serious aerodynamic problems presented to the Committee. The solution is not final, but certain factors have been determined which make it possible to design an airplane which will have normal spinning characteristics. The Committee has found that it is necessary that the vertical fin and rudder be of ample size; that it is desirable to have forward stagger; that the center of gravity should be placed forward within a limited range of position; and that the distribution of weights of the airplane parts should be such that the airplane will have a small inertia coefficient.

Loads on Seaplane Floats. In the development of seaplanes and airplanes having seaplane floats, one of the main disadvantages is the weight requirements of the boat. This has largely been due to the fact that aeronautical engineers were in the dark as to the actual loads imposed on the boat in landing on and taking off from the water. The Navy Department requested the Committee to investigate this problem and to actually measure the water pressure on the bottom of the boat in taking off and landing in rough and in smooth water. Here again the investigation required the development of new and unique types of instruments that would be self-recording and would actually measure the water pressures within one-tenth of a pound. This investigation has been completed on two types of seaplanes, not only the maximum pressures imposed being measured, but also the pressures over the entire under surface of the pontoon, and the information obtained will make possible the economical design of the pontoon from the standpoints of weight and cost.

Propellers. The airplane propeller is one of the most important factors in the satisfactory and economical operation of aircraft. A difference in propeller efficiency of two or three per cent means considerable in the performance, fuel consumption, and cost of operation of the aircraft. The Committee has investigated in the propeller research tunnel metal propellers of the adjustable type, and determined the range of blade setting which will give the maximum of performance. The development of the metal adjustable blade attached to the hub of the propeller has been an important factor in reducing the cost of operation of aircraft, as it is now necessary to have only a few designs of blades which are standardized and which can be attached to the same type of hub, and the variation in performance can be obtained by the adjustment of the blades. In making this practical, the Committee has constructed and released information on an instrument for the correct and proper setting of propeller blades in the field. These instruments are now in use in the Army and Navy services.

Problems of Commercial Aeronautics. In mentioning the contributions made by the Committee to commercial type aircraft, I would cite a few examples of problems submitted to the Committee by the industry and the answers that have been obtained to date.

Cooling and Cowling of Air-Cooled Engines. A large proportion of the commercial airplanes now operating and being constructed in the United States use the Wright Whirlwind engine, the engine used by Lindbergh, Chamberlin, and other transoceanic flyers. The one single question in which the aircraft industry as a unit was interested was to know the proper method of cowling and cooling the Wright Whirlwind engine; to know the drag or resistance of this engine so that computations can be made as to the performance of the aircraft.

The Committee has been actively engaged in studying on full-sized airplanes methods of cowling and cooling Wright Whirlwind engines. A program of tests covering eight different methods has been completed, and the Committee has developed a cowling which reduces the resistance of the engine uncowled, at a speed of 125 miles per hour, from 208 pounds to 128 pounds. This means that if the airplane is flying at 125 miles an hour, instead of requiring 200 horse power it will require only 166 horse power. The saving in operation of the thousands of engines of this type in service with the improved method of cooling and cowling will be appreciable. The drag of the J–5 engine was found in the propeller research tunnel to be 85 pounds at a hundred miles an hour.

I feel that it is important to add that, having the equipment of the propeller research tunnel, the Committee is in a position to supply information to the American aircraft industry which cannot be supplied anywhere else in the world. It is the only tunnel in existence where a full-sized airplane fuselage with engine mounted and in operation can be thoroughly investigated. The importance of information of this character in furthering the interests of American aeronautics cannot be overestimated.

Interference Effects between Wing and Fuselage. Another problem in which the manufacturers were greatly interested was the interference effects between the wing and the fuselage and the possible benefit of curving the wing into the fuselage or supplying a fillet at the connection. An investigation of this problem has been made, and the information obtained that a fillet of 6-inch radius or 12-inch radius on an airplane of the design of the "Spirit of St. Louis" would result in definite increase in propeller efficiency and a reduction in the resistance of the airplane.

Development of Wing Sections. As a result of the investigations of the Committee on the characteristics of wing sections, a large number of American aircraft manufacturers are now constructing and operating airplanes using wing sections developed by the Committee. When it is realized that the wing is the most important item in the design of the airplane making for safety and economy, it is gratifying to the Committee to note that these wings have been selected by the manufacturers without any definite or direct recommendations by the Committee.

Oil Engine Development. The Committee, appreciating the importance of the power plant in the successful and economical operation of commercial air transport, has had under investigation an engine using heavy oil and eliminating ignition, carburetor, and other accessories necessary to the operation of an engine using gasoline as fuel. The type of engine being investigated, known as the compression-ignition engine, will use a Diesel engine fuel, costing one-fourth as much as gasoline and operating at a higher efficiency. The fuel consumption of the gasoline engine is approximately .5 pound per horse power per hour. The heavy-oil engine with a higher compression and a greater efficiency will operate at about .38 pound per horse power per hour.

There were many fundamental problems that had to be attacked in bringing about the successful development of an engine of this type, which must necessarily operate at relatively high speeds, that is, above 1500 revolutions per minute. The contributions of the Committee in this field have been such that the Committee is now looked upon as the leader in the development of engines of this character, and the investigation has reached the point where the Government has contracted with the Westinghouse Company and the Allison Engineering Company for engines of this type.

Another important factor in connection with this development is the elimination in a large measure of the fire hazard, because of the low volatility of the fuel used.

The importance of this investigation can be appreciated when it is realized that the commercial aircraft of the future will probably be a large aircraft having thick wing sections, and heavy oil engines using a reduction gear on pusher type propellers. These engines, besides being economical, are reliable, and the use of a reduction gear and pusher type propeller will largely eliminate noise and vibration, which do not make for comfort in commercial aircraft.

Supercharger Development. As the average airplane will operate at altitudes from sea level to 15,000 feet, and as the horse power of the engine varies from full horse power at sea level to one half that horse power at 15,000 feet, owing to the decreased weight of air available at that altitude, the Committee has seen the necessity of developing an auxiliary to the engine known as a supercharger. This equipment consists of a highly efficient light-weight compressor which maintains at the carburetor an air pressure which will provide full sea-level horse power at altitudes up to and above 15,000 feet. An appreciation of this device is realized when one considers that a large number of our landing fields are at altitudes of 5,000 feet or more, and that in operating on our airways aircraft must climb over mountain ranges at altitudes of 10,000 feet or more. To maintain air speed and to provide sufficient safety in taking off and landing at these altitudes it is necessary to retain full engine horse power, and it is probable that in the future the supercharger will be considered an indispensable accessory to the aircraft engine.

The Committee has been of substantial aid to the Navy in the development of this type of equipment, and at present twenty seaplanes attached to the Pacific fleet are fitted with the N.A.C.A. Roots supercharger, which has not only proved valuable in increasing the performance of the aircraft at altitudes, but has also proved highly useful as an aid to catapulting or taking off from the deck of the battleship. Where the supercharger is used, the horse power of the engine is increased at least fifty percent above that at normal sea-level operation.

G. W. Lewis,
Director of Aeronautical Research, Budget Officer.

22. Frank A. Tichenor, "Why the N.A.C.A.?" Aero Digest (Dec. 1930), 47ff.

[The NACA had its share of critics over the years, but none so vocal and explicit as Frank Tichenor. This particular attack—in which the NACA staff saw the hand of its former employee Max Munk—contributed to the Committee's troubles in maintaining congressional support in the early years of the Depression. Although the NACA refused to answer Tichenor in print (in keeping with its policy of avoiding public disputes), the staff took vehement exception to Tichenor's allegations. (See documents 23 and 24.)]

WHY THE N.A.C.A.?
By Frank A. Tichenor

Here is a matter of such vital importance to the industry that we cannot write of it save with plain words of considerable solemnity. It is a matter to which we respectfully would call the attention of the President. Indeed, we do so explicitly and respectfully, refraining from anything except such a statement as will make facts clear.

In this period of industrial readjustment, particularly in the aviation industry, our thoughts turn to a very important basis of technical enterprise, experimental aeronautical research. A young industry is more dependent on research, and at the same time less able to provide for it, than older and better established industries. Because the Government has been well aware of this situation, nearly all aeronautic research in this country has been financed and carried on by the Federal Government. Foremost in this activity has been the National Advisory Committee for Aeronautics, for which Congress has provided funds. The N.A.C.A. has obtained from Congress funds for the largest, the most splendidly equipped and the most modern laboratories, and facilities for aeronautic research. To all practical purposes aeronautic research in America means N.A.C.A. research. Our thoughts turn in this hour to this research activity, and with full concern for conditions in the aeronautic industry, we ask ourselves whether the N.A.C.A. has discharged its duty well, whether it has given to the industry the full return to which it is entitled for these appropriations.

How greatly aeronautic progress depends upon research has indeed been fully realized by those in charge of N.A.C.A. work, as is indicated in the annual report of the N.A.C.A. for 1921 (page 5):

"Substantial progress in aeronautical development must be based upon the application to the problems of flight of scientific principles and the results of research."

Research activity of the N.A.C.A. has been going on for more than ten years. The first appropriation for a wind tunnel having been made in 1917, this tunnel was reported to have been completed in 1918. Experts tell us that a year is ample time to build an ordinary small wind tunnel. Nevertheless, although the wind tunnel was completed, it was not then put into operation. In 1919, the tunnel was again reported not yet in operation. Finally, in 1920, the same tunnel originally reported as finished in 1918, was once more reported as finished. The year 1920, therefore, we are entitled to consider as the beginning of research activity, particularly inasmuch as an engine laboratory and free flight test facilities had been announced as completed in 1919.

This fact is important because the results of research cannot be judged from the activity of one day, or one month or even one year. After ten years of uninterrupted activity, however, with continuous liberal financial support, the N.A.C.A. can be judged according to the results derived from its research work and an estimate can be made of what we have a right to expect in the future. Let us, therefore, review these results and ascertain what the N.A.C.A. has achieved.

The standard by which the results of research should be appraised is defined by the N.A.C.A. itself. Repeatedly, its annual reports have stressed *scientific* research as of paramount importance. For instance, almost all reports close like that of 1927 (page 76): "Further substantial progress is dependent largely upon the continuous prosecution of *scientific* research," and farther below on the same page, "its (N.A.C.A.'s) work in the fields of pure and applied research on the *fundamental* problems of flight." The latest report, that for 1929, states (page 87): "The most important active influence upon aeronautics has been the farsighted and constructive policy of the Federal Government, liberally supported by Congress and the President, in providing for the continuous prosecution of organized *scientific* research." In the 1926 report we find (page 69), "The more *fundamental* investigations are undertaken by the Committee in its own laboratory," and (page 68), "to conduct investigations of a truly *scientific* character." (The italics are mine.)

We could easily quote other passages from N.A.C.A. publications to the same effect. The N.A.C.A. is not an aircraft factory; it is not interested in the properties or the development of any particular airplane. More general scientific investigations are its domain. It is charged with the responsibility of furnishing information concerning aeronautics as a science.

Nor do the annual reports of the N.A.C.A. leave any doubt about what is meant by "scientific research." That of 1922 (page 48), defines the term clearly:

"By scientific research is meant the investigation by trained men in a properly equipped laboratory of the *fundamental phenomena of nature*. . . . All progress depends upon the acquisition of knowledge, of new knowledge. This can be obtained only by long continued investigations *directed by men who know the problems and the methods used for their solutions.*"

Perhaps the best standard by which to judge the results of ten years of N.A.C.A. research is in terms of returns for the funds spent. Even with a small appropriation there is no upper limit to what can be obtained in the way of research if that research is directed "by men who know. . . ." There is, however, a lower limit to what ought to be obtained for a given amount of money. It stands to reason that we can expect more for an expenditure of $2,500 than for one of $250, and more for one of $25,000 than for one of $2,500.

The N.A.C.A. has spent on each of its research items undertaken more than $100,000, and we have a right to count on important results from $100,000 researches. This average expenditure for each problem investigated is computed by dividing the sum of the money spent by the number of problems undertaken. Thus far the N.A.C.A. has received $4,936,370 in appropriations. Approximately $4,800,000 has been spent (presuming the expenditure of the whole sum of $1,508,000 appropriated for 1930). The results of its research are laid down in eighty-eight Technical Reports. All other N.A.C.A. Technical Reports contain information obtained from outside sources, the N.A.C.A. acting only as publisher. This means that more than $50,000 has been spent for each report on a research project. It means much more per research, for at least four reports are always issued on the same research. This would give $200,000 per research item. Allowing for those research projects not yet completed for which no reports have yet been published and allowing also deductions for other expenses of the N.A.C.A., we are certainly justified in estimating that more than $100,000 has been spent for each research undertaking. Since 1925, and until 1930, the annual appropriation for the National Advisory Committee for Aeronautics has been approximately $500,000. This year it was increased to $1,508,000. No one can claim that during any one of the last four years more than five research problems have been finished and the results made available to the public. One hundred thousand dollars per research is perhaps too moderate an estimate.

It is pertinent to ask whether really useful scientific results have been obtained, and if not, to inquire about the reasons why research so liberally supported failed to furnish an adequate return. This sum cannot be considered exorbitant if valuable results have been obtained from it.

If we make a more detailed analysis of the N.A.C.A. research of the past ten years, we find that it can be classified into wind tunnel research, free flight research on actual airplanes, and engine laboratory research.

In the engine laboratory, tests have been conducted with a view to improving the efficiency of gasoline aircraft engines by the choice of the best compression ratios, richness, and mixtures, and the like. That work would be valuable if important results had been obtained, but we doubt whether, lacking this research, any one existing engine would be worse. To say the least, this study and experiment has not been of a scientific nature. In addition, the Diesel engine was studied, likewise not a scientific or new phenomenon, and no tangible results were achieved, except possibly in the case of the spray research with solid injection.

The free flight researches gave valuable information concerning the maximum accelerations and maximum pressures occurring in maneuvers. Also some practical information regarding the ice hazard and similar subjects was obtained. Apparently the only fact demonstrated in the study of the supercharger was that such a device increases the available horsepower, and that was known before. This can hardly be considered an outstanding success. On the whole it can, nevertheless, be said that the free flight research has been the most beneficial conducted by the N.A.C.A. At the same time it can be said that no free flight test has been a scientific test nor dealt with investigation of fundamental phenomena of nature. Test flights conducted over a period of ten years, with the aid of good instruments, cannot but yield some valuable information, especially at a time when flying is new, but they are not likely to advance fundamental science.

The class of wind tunnel research should correspond most to the description "scientific." Therefore, we ought to consider it in more detail in order to find there at least some of the promised scientific work. In this category the pressure distribution work of the N.A.C.A. showed only that wings should be rounded at the tips, which was known before, and which could be and was demonstrated in the course of natural industrial development. Merely to make pressure distribution measurements is not scientific. We are sometimes inclined to believe that it would be better for wind tunnel research if it were more difficult to do this kind of work; an abundance of patience is necessary but not much creative mental effort. The results are not of great practical value, because they are made under steady wind tunnel conditions, whereas the largest pressures occur under unsteady flight conditions. For this reason, the pressure measurements made in flight tests are much more valuable.

In addition there have been wind tunnel tests on complete airplane models, and drag measurements on airplanes and airplane parts. This research cannot yield new results of general value, and is therefore outside the scientific research the N.A.C.A. is charged to undertake.

During all of the ten years, much time and effort has been spent on a series of tests undertaken to standardize wind tunnels throughout the world. This work showed merely that different wind tunnels give slightly different results and that these differences cannot be predicted—which facts we knew before. Tests referring to wind tunnel technique are secondary anyhow. Someone has claimed that all wind tunnels could continue to do research even if no airplanes existed. They could, but we would not accept such work as useful unless science had been advanced.

Propellers have been investigated and found to possess a certain thrust and torque. Interesting, but again not scientific progress, not even technical progress.

We come at last to the research having most of the scientific element in it—that dealing with the rotating cylinder. This stirred the imagination when the first tests were made and showed undreamed-of lifts. Right now, a very prominent manufacturer is making experiments along that principle. Unfortunately, the first tests along this line were not made by the N.A.C.A. On the contrary, the N.A.C.A. refused a suggestion in 1921 to measure this phenomenon. Several years later, it did repeat measurements made abroad without adding one new thought or result.

The Autogiro is the most painful subject in connection with the N.A.C.A. research. The N.A.C.A. had the priority in this new and perhaps most important invention of recent years. Autogiro models were investigated in 1922. It is hard to believe, but nevertheless true, that these tests were never published in a Technical Report. Five years later, after the practical value of the Autogiro had been demonstrated abroad, the results were published in mimeographed form, giving evidence of an opportunity to contribute to scientific progress which was woefully neglected.

In the investigation of auto-rotation of wings, it was demonstrated that, in a wind tunnel, wings can be made to rotate like windmills. This has hardly any bearing on or connection with the spinning of airplanes. It can hardly be called a research, but rather only making pretense of research. No airplane designer gives any attention to such tests, and science rejects them entirely.

A study of boundary layer control is on the program of the N.A.C.A., according to its statement, but no report has appeared in print on the results and we have not been apprised of any progress. This should be the most important subject of the work, but in fact hardly anything seems to have been done except the repetition of some work abroad.

Finally there is the wing section research. This is the only line in which the N.A.C.A. has contributed to aeronautics by way of its own experimental research. The M wing sections were developed by the N.A.C.A., in its wind tunnel, and at least two of them have been adopted in practice, being considered superior to older ones. Accordingly, the N.A.C.A. report for 1924 (page 50) says: "satisfactory progress has been made in the science of aerodynamics during the past year. . . . One important result of wind tunnel investigations has been the development of a number of remarkably efficient wing sections of adequate thickness for economical structures. *It is desirable that this development continue substantially along the present course.*"

This was indeed desirable, for the investigation was intended only as the first and preliminary step of a more systematic research. Much better wing sections were expected from the next series of tests, as the report indicates (page 59), "It is believed that a fruitful field for research lies in the determination of these sections which have a stable flow with good aerodynamic properties." In the interim, however, there has been no evidence of further work and the M section research, so admirably begun, has never been continued.

We do not believe that we have overlooked a major research item of the N.A.C.A.; we are certain we have not overlooked a successful one. The N.A.C.A. was officially awarded the Congressional medal for its low drag cowling. Apparently, even the friends of the N.A.C.A. consider this the most outstanding of the research projects completed. Yet, in the true sense, this cowling work was a development rather than an original work. Moreover, because it had reference to special airplanes and engines, it cannot be regarded as having general value. Therefore, it cannot be considered scientific work. It does not involve the study of new and fundamental phenomena of nature. Its doubtful value in this connection is clearly contrasted with the research of similar aim—though along entirely different lines—carried on at the same time in England. The Townend Ring is definitely superior to the N.A.C.A. cowling. It is the outcome of strictly scientific research carried on with scientific spirit, involving the systematic exploration of new and fundamental phenomena, and incurring relatively little expense. It represents more brain and less expenditure than for the N.A.C.A. cowling research.

The results of the N.A.C.A. experimental research are not, in our opinion, an adequate return for the money spent. There is hardly one research project of scientific value, and only a few of technical value. There is an enormous gap between the principles of research laid down and those applied.

It cannot be denied that there is keen feeling of disappointment throughout the industry about the outcome of the N.A.C.A. research. Every year the industry gathers at Langley Field to acquaint itself with the latest results of the research going on, but every year it is presented with stone rather than with bread. New laboratories and instruments are exhibited but no new results worth speaking of.

Responsibility for the N.A.C.A.'s failure to make substantial contributions to aeronautic science does not rest entirely on the organization itself. General supervision of the research undertaken is in the hands of committees which are composed of members serving without compensation. Under these circumstances, they cannot give much time to this research; and after all, they are not to be blamed for its shortcomings. Scientific knowledge cannot be amassed by a committee any more than an opera can be written by a committee. The capable and patriotic members of the several research committees feel that they can give best service by keeping their hands off, by assisting with advice and suggestion only, without showing too much initiative.

The real responsibility would seem to rest, therefore, upon the director of research. Is he one who knows "the problems and the methods used for their solution"? We fear not. But then it must be remembered that this director exercises the direction of the research from a distance of 200 miles, and as an auxiliary duty only. His primary duty is that of an executive. In the first place he must practice diplomacy and exercise organizing talent: only secondarily need he exhibit any scientific spirit. Most of his direction of the research is done over the long-distance wire, or on occasional visits. These facts, together with his normal duties which stand in distinct contrast to the duty of research supervision, and require entirely different capabilities, make it plausible to believe that the director of research is not in a position properly to discharge his duty. As one important reform that will improve the present conditions, we suggest that the Langley Field laboratory be separated entirely from the Washington political office of the N.A.C.A. and be put in charge of a capable research engineer who would be fully responsible for the research and for it only.

As it is, the true initiative must come from the local head of the laboratory, and from the heads of the single divisions. We expect most from the aerodynamic sections. It is now a fact that both positions, the head of the L.M.A.L. and of the aerodynamics division, have been occupied in recent years by men who are decidedly not research engineers at all. Neither of them has ever contributed anything to science, and neither of them expects to do so. They are mere routine engineers, and hardly that; they are mere bureaucrats, signing letters and unwrapping red tape.

This brings us to the question of the N.A.C.A. staff. Friends of the N.A.C.A. have claimed that the staff has suffered great losses because the industry has induced its best men to leave by offering them lucrative positions. This does not sound probable. In the first place, a capable research engineer does not leave his work if he has found favorable working conditions, and is progressing satisfactorily in his work. The fact that nearly all good research engineers have left the N.A.C.A. constitutes in itself a reproach to the management. From inside information we know that most engineers left of their own initiative, because they were dissatisfied with the management. They are now employed in industry, and most of them did not leave as friends of the Committee. During these ten years, the head of the laboratory at Langley Field has changed four times, and two and a half years is about the average time the engineers used to stay. There must be a reason for this state of flux in the personnel. Most of the research engineers are young graduates and the few older men who have stayed with the organization are for the greatest part less capable than those who left. Jealousy and petty politics have always played too great a part in the activities at Langley Field. The spirit of research and scientific work was never really encouraged by the management. Nobody can carry on research work successfully if he is compelled to devote a great part of his time to fighting for the cooperation of others to which he has a right, and fighting off the aggressiveness of his colleagues. The failure of the National Advisory Committee for Aeronautics is the failure typical of so many public organizations. There is no effective check on what is accomplished. If the results of the N.A.C.A. could be computed according to their worth in dollars and cents, the Committee would long ago have been bankrupt. But it is not a money-making organization, it is a money-spending organization. That leaves much energy free, and unfortunately the conditions in such a case are favorable to the survival of those most unsuitable for carrying on scientific research.

The activity of the N.A.C.A. has become a mere building of new laboratories without distinct ideas of what to do with them after they are built, and it has become a mere weighing and measuring of less value than the weighing of a grocery clerk. No concerted efforts are made to elevate science; no efforts are made to apply the results of the tests to any logical system, to digest them, and to interpret their significance in the sum of general knowledge. The truth is that the tests cannot be interpreted that way because the program has not been guided by scientific reasoning. Weighing for weighing's sake is not scientific research, but at the best a kind of indoor golf.

We urge that radical changes in the management be made with the view to improving the conditions to the end that real and honest talent may be attracted to the N.A.C.A. Only then will there be some prospect of an intelligent use of the research equipment and a reasonable return for the money spent.

Let's devote a period of thought to wondering if these large appropriations devoted to the N.A.C.A. have served, are serving, or will serve the industry.

Let's hope that Congress, yes, and even the President of the United States, will give consideration to the self-same subject.

Let us spend money, certainly—no detail of aviation should be stinted—but let us have men in charge of its expenditure who will see to it that the money which we spend shall count.

23. Memorandum, Elton W. Miller to Engineer-in-Charge, "Article in Aero Digest for December," 19 Dec. 1930:

[This rebuttal to the Tichenor article (document 22) is one of the weaker ones that emerged from the NACA. Paragraph 6, for example, rather confirms Tichenor's opinion than refutes it. Nevertheless, the memo provides an insight into the nature of research as understood by the NACA, as well as examples of what the Langley staff took pride in. A handwritten note on the original described the *Aero Digest* article as being Max Munk's work.]

1. With reference to your memorandum of December 11, I have given some consideration to the various questions contained in your memorandum, and before answering them specifically, I feel that it is necessary to define fundamental phenomena of nature and scientific research. A study of the phenomena of nature doubtless includes a study of how air flows about bodies. Some phases of this study might be classified as fundamental or basic, and others which might be the outgrowth of the first

and planned to cover in greater detail certain phenomena would not be fundamental. They might have a definite practical object.

2. I believe very little of our work could be classified as fundamental, according to general acceptance of the term, but defining science as "accumulated and accepted knowledge, systematized and formulated with reference to the discovery of general truths on the operation of general laws," and research as "careful or critical examination in seeking principles or facts," I think that practically all of our work can be classified as scientific research. I assume that research need not necessarily be aimless to be scientific, but that it may have a definite practical object. This is borne out by the Organic act which charges the Committee "with the supervision and direction of the scientific study of the problems of flight with a view to their practical solution—." The scientific method of research is believed to be that of systematic search for truth, and apparently it must be directed toward the discovery of general laws. Most of our work falls under this head. I will now take up your questions, using the corresponding numbers.

5. Some investigations are more systematic than others, and some lead to more general conclusions than others. Among such may be mentioned the investigation of pressure distribution and acceleration on the PW-9 pursuit airplane, the F6C-4 airplane, and the Douglas M-3. The distribution of pressures was systematically investigated over various parts of the airplanes in question throughout various maneuvers. It is possible from the accumulation of information to draw rather general conclusions, and to obtain information for the study of more specific problems, such as tail loads, leading-edge loads, and the study of load factors. Another investigation which has been systematically carried out has been that of the maneuverability of various airplanes, and while it has not yet progressed far enough to lead to general conclusions, there is every reason to believe that it will do so.

6. There are two main purposes in making wind tunnel tests on complete models of airplanes, particularly in the Variable Density Tunnel; first, to compare the aerodynamic characteristics of airfoils with those of the complete models on which the airfoil sections are used; and second, to show the validity of the principle on which the Variable Density Tunnel operates. This may be done by comparing the results of tests in the tunnel on a model of an airplane with the results of tests on the airplane in flight.

7. The correspondence on file does not show whether tunnel standardization was suggested and started by this Committee or by the British National Physical Laboratory. We have a letter from the N. P. L. dated May 27, 1922, requesting the Committee to make tests of the N. P. L. airship models. Our Research Authorization No. 70, on which this work was done, was approved on January 26, 1922. It seems likely that the initiation of this R. A. resulted from some preliminary correspondence with the British, not in our files at present.

8. Among the most systematic and hence most scientific of the investigations conducted thus far on propellers have been those of the effect of high tip speeds on propeller efficiency, and the effect of body interference on propeller efficiency. In the first, two families of propellers of different pitches were used at various r.p.m.'s, and hence at various tip speeds. This series of tests leads unmistakably to a general conclusion regarding the effect of tip speed on propeller efficiency. In the second, a series of propellers of different diameters was tested in front of a single body. In another investigation, the effect of changes in blade form was studied by tests of a systematic series.

12. The tests of twenty-seven airfoil sections in the Variable Density Tunnel was completed in the later weeks of 1924, and the tests of seven frequently used sections, early in 1925. It was the desire of the tunnel staff to continue this investigation, and progress was laid out to this end. . . . Although this progress was approved by Dr.

Munk and by Mr. Lewis, the records do not show why it was not carried out. They do show, however, that Dr. Munk had other plans which he wished to investigate. These include. . .:

1. The Slotted Wing, Technical Memorandum 282, Figure 12 to be tested at several pressures.

2. Five Elevator Wing Sections with Flap, Figures 1-5 to be tested at 20 atmospheres with different positions of the elevator proper.

3. . . . Investigation of Influence of Aspect Ratio of One Monoplane Airfoil on Scale Effect.

4. Investigation of One Biplane Cellule.

All of these investigations, with the exception of the first, were carried out, and occupied the tunnel for a period of months. In addition, tests were made on the Sperry Messenger airplane model, and on a wooden replica of the N. P. L. airship model. The CYH airfoil was built and tested January 1, 1926. While it was, doubtless, Dr. Munk's intention to continue this investigation, since he speaks of the tests of the twenty-seven sections as tests of the first systematic series of airfoils, he did not suggest continuing the progress at any time during his residence at the Laboratory, which continued until March 31, 1927.

13. The investigation of the Townend ring by the British was conducted in a somewhat similar manner to the work on our N.A.C.A. cowling, except that their work was done only on models, rather than on a real engine, and they had no means of measuring the effect on the cooling of the engine. It might be thought by some that the investigation of the Townend ring was more scientific because the investigators started out to accomplish one thing (to study the interference of a ring in front of a body), and stumbled upon a scientific truth which could be applied to an entirely different problem; while, in the case of our own cowling, the investigators started out with a definite practical problem—to solve that of finding out how much of the engine could be covered by cowling, and thus, how much the drag could be reduced without interfering with cooling. Mr. Townend was apparently studying the question of interference in connection with a propeller investigation when he realized the possibility of reducing the drag of an air-cooled engine by applying the ring.

It is deemed to be not the purpose of this Laboratory to devote itself to fundamental scientific research as distinguished from that which has a definite practical object. It is the aim of the Laboratory, and I believe it is in large measure realized, to apply scientific methods to the solution of the practical problems of aerodynamics. The conditions at the Laboratory, described in the above article, the dissatisfaction of personnel, and questionable value of some of the results are believed to be more true of the period a few years ago, with which Dr. Munk is personally familiar, than of the present period. The interest of the personnel in the work of the Laboratory and the enthusiasm for the work at hand is believed to be as great as will be found in many research organizations, and much greater than in most Government establishments. This is borne out, at the present moment, by the fact that a number of the personnel in each section of our division are at work when they are entitled to leave for the remainder of the year. An effort is being made throughout the Laboratory to conduct every investigation in a thorough and systematic manner. Greater care is being taken to secure accuracy, and results are being more carefully checked than ever before, and I believe that the conclusions reached as a result of our work will be of more and more value as time passes.

ELTON W. MILLER,
Senior Aeronautical Engineer.

24. Memorandum, H.J.E. Reid to George Lewis, "Comments on the article in the December 1930 issue of Aero Digest, entitled 'Why the N.A.C.A.?'" 2 Jan. 1931.

[Answering the charges leveled against the NACA by Frank Tichenor (document 22), the engineer-in-charge at the Langley laboratory reveals information about the workings of the laboratory that appears nowhere else in print. To the hyperbole of the Tichenor piece, Reid responds characteristically with documentation, moderation, and specificity. He does, however, leave unanswered several of Tichenor's general criticisms.]

1. I have read over the article of reference several times, and have looked up some information in the Laboratory's files which is explained below, and I am forwarding copies of memoranda from Messrs. Miller and Kemper covering some of the statements made in the article.

2. In looking over the article I was first impressed by the misstatement regarding the completion date of the Atmospheric Wind Tunnel, which was not reported as completed in 1918, but was officially opened in 1920. The Annual Report for 1919 states that the tunnel had been completed but not put into operation on account of the inability of the local power company to supply power. It then became necessary to install a small power plant to furnish direct current temporarily.

3. In regard to the cost of researches, or "research items", as the article states, it is very difficult to arrive at any figure which we could call the cost of a research. A good many of the research authorizations which have been issued have been cancelled because the work has been done under other research authorizations or it has been later found that the research proposed would not be fruitful. In the early days of the Laboratory a relatively small amount of aeronautical information had been acquired, and it was quite natural that many researches might be proposed which, in light of further experience and information, would be proven to be of small value or uneconomical. These researches were, of course, cancelled in many cases without ever having conducted any research under the particular authorization. Many research authorizations were so broad that they really covered a number of separate researches, each of which led to good reports containing valuable information. It is difficult, or almost impossible, therefore, to say just how much the so-called "research items" undertaken actually did cost. It is known, however, that results of the researches at the Laboratory are reported in more than 88 technical reports, the Laboratory itself having contributed during that period 129 technical reports and 131 technical notes, all of which are valuable. In addition, a considerable amount of money has been spent by the Committee on research at other points than Langley Field, for which there have been many reports and technical notes published by the Committee. No mention, of course, is made of technical memoranda and aircraft circulars, which are of definite value to the industry and rightly come under the work of the Committee in obtaining and disseminating information.

4. While the appropriations during the past 11 years, including the fiscal year 1930, have been approximately $4,963,000, not all of this has been spent at the Laboratory. It is believed that you are in a better position to know what percentage of this amount has been spent at the Laboratory. There still remains, however, the value of the plant equipment, including buildings, wind tunnels, hangars, airplanes, instruments, stock, etc. . . .

5. Regarding the statement that the N.A.C.A. refused the suggestion in 1921 to measure the phenomenon of the lift on a rotating cylinder, we find that the Laboratory has no information in its files regarding such a suggestion as early as that date. The first mention of anything of that sort in the files is contained in the Minutes of the

Meeting of the Subcommittee on Aerodynamics, September 19, 1923, where Mr. Bacon* reported that three cylinder models had been prepared for test at Langley Field. This work was reported in 1924 in Technical Note 209, by E. G. Reid.

6. In regard to the autogiro, as mentioned in the article, there is no evidence in the files to indicate that tests on an autogiro model, as such, were ever made. The correspondence back as far as January, 1919, shows that propellers were being studied with a view to their application to the helicopter, and in 1921 tests were carried out on a propeller mounted in a wind tunnel, measuring the drag at various angles of yaw and with various amounts of braking. Later on, work was done on feathering propeller blades, and correspondence in 1923 and 1924 indicates that there was a paper prepared by Bacon and Munk on "Model Tests on the Economy and Effectiveness of Helicopter Propellers." The Laboratory correspondence does not indicate that this type of work showed very much promise, and as I was not personnally connected with any of that work I am not in a position to recall any of the details of the tests.

7. Mr. Miller has covered the question of the wing section research and I distinctly recall that Dr. Munk, during his stay at the Laboratory, had other work for the Variable Density Wind Tunnel which he wanted to push ahead of the further work on airfoils. As you know, a systematic family of airfoils has been made up, and work will soon start on this investigation. It is expected that results will be available from a great many, if not all, of the family of airfoils, for presentation at the next Manufacturers' Conference.

8. It was interesting to read the startling statement in the article regarding the Townend ring, especially the statement that it is definitely superior to the N.A.C.A. cowling. From all accounts, it seems that every improvement the British make in the Townend ring brings it closer to the original N.A.C.A. cowling as flown on the AT-5 airplane. The method of conducting this investigation, it would seem to me, was quite similar to that which the British used, except that we had the definite goal of reducing the resistance of the air-cooled engine. The methods employed were much the same, except that, instead of using rough models, the Committee used an actual engine and airplane, which led to definite conclusions immediately.

9. It is true that a great many good research engineers have left the Committee, but it is not true that most of them left because they were dissatisfied with the management. There were a few engineers who left because of dissatisfaction with conditions, but they, in general, were not to be classed as good research engineers. There were at least two, Mr. E. G. Reid and Mr. Paul E. Hemke, who were very strongly influenced in their decisions to leave the Committee because of their unpleasant relations with Dr. Munk. For the most part, however, the engineers have left because of the fact that many of them were interested in the industry and not in research, and as a result of their experience at the Laboratory could command high salaries in the industry which, it is well known, was paying abnormally high salaries to everybody connected with it. The fact that several of the engineers who have left the Committee have been interested in returning to the Committee, and the fact that Mr. Weick actually has returned after serving some time in the industry, indicate that the conditions here at the Laboratory are not as described in the article.

10. As for the Manufacturers' Conference, it is believed that the increasing attendance and interest shown by the manufacturers are a definite acknowledgement of the fact that they do get information of value from the Committee.

H. J. E. Reid,
Engineer-in-Charge.

*David L. Bacon.

25. Minutes of the NACA annual meeting, 22 Oct. 1931, pp. 10–13, adoption of rules governing work done by NACA for industry.

[The question of using NACA staff and equipment to conduct research for industry was a troubling one throughout the Committee's history. This, the first formal declaration of policy, prompted discussion of two of the stickiest aspects of the problem: costs, and proprietary rights. Note that in the discussion no member of the Committee observes that the policy would favor large well-capitalized manufacturers over small inventors of modest resources who might nonetheless have more worthwhile projects. (See documents 26 and 42.)]

Regulations Governing Work for Private Parties. The Chairman stated that the Committee had arrived at that stage in its history where, due to the possession of unique equipment, it was necessary to provide for the conduct of work on the request of, and at the expense of, private parties. The Secretary stated that the act establishing the Committee authorized it to proceed under rules and regulations approved by the President; that Rule 2 of such rules and regulations provides that the Committee "under regulations to be established and fees to be fixed," shall exercise its functions for the benefit of private parties provided they defray the cost involved. The Secretary then read a draft of proposed regulations and fees governing work for private parties as follows:

1. Any American citizen or American firm, association, or corporation which desires the Committee to conduct any investigation or test will make application by letter addressed to the Committee stating definitely what is wanted.

2. If the investigation or test relates to aeronautics and necessarily involves the use of facilities not available in the United States outside the Committee's organization, the Director of Aeronautical Research may authorize the investigation or test to be conducted at the Langley Memorial Aeronautical Laboratory.

3. The engineer in charge of the laboratory will submit to the Committee an estimate of the cost based on all direct labor and material, plus 100%, and the Secretary will then require the posting of a special deposit in the form of cash or certified check payable to the order of the National Advisory Committee for Aeronautics in an amount equal to the total estimated cost, and will notify the laboratory when the required deposit has been received.

4. If a model or models are required for any investigation or test, same should be provided by the party desiring the work and be sent, charges prepaid, to the Langley Memorial Aeronautical Laboratory.

5. The engineer in charge of the laboratory will issue the necessary job orders, keep an accurate record of cost, including cost of preparing report and returning model, and will transmit report to the Committee along with statement of cost.

6. If during the conduct of any investigation or test it appears to the engineer in charge that the special deposit may not be sufficient to cover the total cost involved, he shall promptly notify the Secretary. The latter will then require an additional deposit and promptly notify the laboratory of its receipt.

7. The engineer in charge shall stop all work on any investigation or test before the accrued costs exceed the total amount on deposit.

8. Upon completion of an investigation or test the Secretary shall cause an amount equal to the total cost to be deposited in the Treasury to the credit of "Miscellaneous Receipts" and the balance, if any, remaining in the special deposit to be returned to the depositor.

9. The results of all such investigations and tests so conducted shall upon request of the depositor be kept confidential as far as the public is concerned, but shall in the discretion of the Committee be available for Government use.

Dr. Burgess* referring to paragraph 8 questioned the wisdom of depositing the amount earned by the Government to the credit of "Miscellaneous Receipts" and announced he would oppose that provision, citing the experiences of the Bureau of Standards in similar matters. General Pratt† agreed with Dr. Burgess. The Secretary stated that as the depositors would be required to furnish models there would be practically only labor and power costs involved, and that it would not be necessary nor practicable to engage additional temporary employees for such work; wherefore if the costs were deposited to the credit of the Committee's appropriation they would at the end of the year remain an unexpended balance in the Committee's appropriation and might just as well be deposited in the first place to the credit of "Miscellaneous Receipts". He added that if the volume of such work increased to the extent that it became necessary and practicable to employ additional personnel on account of such work, then the Committee would have need for the use of such additional funds and at that time could meet the situation by changing its regulations.

Mr. Guggenheim** questioned the proposed policy of making any charge, saying in effect that if the Committee deemed the work worth while it should be done without charge, and if it deemed the work not worth while it should refuse to do the work even at the expense of private parties. The objection made to this procedure was that if the Committee were to do the work without charge it might be burdened with a great many requests, and if it were to refuse to do work deemed not worth while, it would be in a vulnerable position and open to charges of discrimination. General discussion ensued in which all the members participated. . . .

A separate vote was taken on the question of whether the amount earned by the Government should be deposited to the credit of "Miscellaneous Receipts" or to the credit of the Committee's appropriation, and the result was four votes for each plan; whereupon the Chairman ‡ to break the tie voted in favor of depositing such funds to the credit of "Miscellaneous Receipts."

Mr. Warner[1] referring to paragraph 9 raised the question as to the propriety of allowing the results to be kept confidential and suggested that they become public property either promptly or within a brief period of time, e.g. six months. General discussion followed in which the right of the Government to the use of the results was not questioned, but it was maintained on the one hand that the depositor had a right to require that the results be not made public, and on the other hand it was maintained that since the work necessarily involved the use of expensive Government equipment, the Government had the right not merely to the use of the results for Government purposes but also the right to make the results public for the general good of aviation. The point was made that if the results were favorable in whole or in part the depositor would probably advertise them and use the Committee's name, and might state only such of the results as were favorable and thereby force the Committee in fairness to the public to state all of the results, and that therefore the Committee might just as well

*George K. Burgess, director, National Bureau of Standards.

† Brig. Gen. Henry C. Pratt, U.S. Army, chief, Materiel Division, Air Corps, Wright Field, Dayton, Ohio

**Harry F. Guggenheim, president, Daniel Guggenheim Fund for the Promotion of Aeronautics.

‡ Joseph S. Ames

[1] Edward P. Warner, editor, *Aviation*

publish the results in the first place. The suggestion was made that the Committee's report on a test omit the depositor's name and the trade name of the article tested, and that the depositor not state the Committee's name in announcing favorable results.

After further discussion the question developed as to whether the publication of the results should lie in the discretion of the Committee or in the discretion of the depositor. On this question a vote was taken which showed the members divided four to four; whereupon the Chairman, to break the tie, voted in favor of reserving to the Committee discretion as to publication of results.

It was recorded as the sense of the meeting that the Secretary should circulate a revised draft of paragraph 9, and subject to the approval of such draft by a majority of the members it was, on motion duly seconded and carried,

> RESOLVED, That in accordance with Rule 2 of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics the proposed regulations and fees governing work for private parties or organizations as revised be, and the same are hereby, approved.

The revised draft of paragraph 9 as approved subsequent to the meeting reads as follows:

> 9. The results of such investigations and tests shall be furnished promptly to the depositor, be made available for the use of the Government, and may, in the discretion of the Committee, be published or otherwise released for the information of the public, under such restrictions as the Committee may deem proper to impose.

26. Orville Wright to John Victory, 6 Nov. 1931.

[Orville Wright served on the NACA longer than any other member—28 years—but he seldom played an active role. Like several other members from private life, he was on the Committee to grace the letterhead and to add the weight of his reputation to the NACA name. When he did voice a strong opinion, as in this letter, he could be counted on to speak frankly, individualistically, and often in defense of the small inventor and entrepreneur who harked back to the early years of aviation. Here he takes exception to the policy established in document 25.]

November 6, 1931.

Mr. JOHN F. VICTORY, *Secretary,*
National Advisory Committee for Aeronautics,
Washington, D.C.

Dear Mr. Victory:

I will not be able to be present at the special meeting of the Executive Committee of the National Advisory Committee for Aeronautics on next Tuesday, November 10th.

I am returning enclosed your letter of October 23rd with the draft for paragraph 9 of the new regulations governing work for private parties. I believe the draft represents the action of the Committee and, therefore, I approve it, although I do not myself believe in making public the reports of investigations or tests paid for by private parties, except with their consent. So long as this rule is retained by the Committee, no one, I believe, who has a really novel or valuable idea will have it tested by the Committee; and therefore all of the tests made in the tunnel will be of inventions of minor importance.

I think the inventor is rendering a public service, even though he may patent his invention, when he puts the invention on the market, so that use of it can be secured by the public. For this reason I think that our Committee would be serving our

Government and our people at large when it makes tests of inventions for private parties on a strictly confidential basis.

Sincerely yours,

(s) ORVILLE WRIGHT.

27. *Joseph S. Ames to F. H. LaGuardia, 24 Feb. 1932.*

[Congressman Fiorello H. LaGuardia was an aviation enthusiast and a friend of the NACA. When it was proposed in the early 1930s to transfer the NACA to the Department of Commerce, LaGuardia asked the committee for ammunition to fight the move. In this letter, NACA Chairman Joseph Ames employed the defenses characteristic of the Committee: he cited the practical uses made of the Committee's researches, the economies it had effected, and the endorsements of its clients.]

My dear Mr. LaGuardia:

In response to your request of February 22, I am enclosing a copy of the Seventeenth Annual Report of the National Advisory Committee for Aeronautics, blue-penciled to indicate the principal activities of the organization, and also a memorandum relating to the present and future need of continuing the Committee.

The opposition the Committee has had in the past has not been formidable nor direct, with a single exception, and that was the action in December, 1925, by the Department of Commerce, not appreciating the real functions of the Committee, in incorporating in the original Senate draft of the Air Commerce Act of 1926 a section transferring the Committee to the Department of Commerce and making the Assistant Secretary of Commerce for Aeronautics Chairman of the Committee. That was approved by the Senate Committee on Commerce without the knowledge of the National Advisory Committee nor of the War or Navy Departments. After the bill was ordered favorably reported, one member of the Senate committee was apprised of the opposition of the War and Navy Departments and polled his colleagues, with the result that the bill was actually reported with a committee amendment striking out the objectionable section.

Aside from this incident, there has been no move by any committee of Congress to change the status of the National Advisory Committee since it was created as an independent establishment in 1915; nor has there been any effort other than that of the editor of the magazine *Aero Digest*, Mr. Frank A. Tichenor, who suggests that the National Advisory Committee for Aeronautics be eliminated "through the simple process of merging it with the Bureau of Standards." This reckless suggestion now current is made by one who is not familiar with the real functions of the Committee in coordinating the work of the Bureau of Standards, along with that of other agencies of the Government concerned with aeronautics. Furthermore, the author of the suggestion has never to our knowledge visited the Committee's laboratories, and has no evident qualifications to evaluate the results of scientific investigations in aeronautics.

The Committee as a coordinating agency in aeronautics brings about the efficient use of the facilities of all agencies of the Government. On fundamental problems relating to aeronautics the Committee is a clearing house for the Army, the Navy, the Department of Commerce, and also the aircraft industry.

The Committee has received many voluntary expressions from aeronautical authorities, including the most competent engineers in the aircraft industry, complimenting the organization on its effective work. For your information I am enclosing some extracts showing some of the viewpoints of others.

The National Advisory Committee for Aeronautics is not only an effective agency for coordination and prevention of duplication in the field of aeronautical research, but is also a service agency, serving the needs of the other governmental agencies concerned with aeronautics. It is a recognized principle in governmental organization that coordinating agencies and service agencies should remain independent.

The air organizations of the War and Navy Departments rely upon the Advisory Committee for the scientific knowledge and fundamental information that underlie progress in military and naval aircraft. The Department of Commerce and the aircraft industry are necessarily dependent also upon the Committee for the scientific investigation and study of fundamental problems.

The Government expends each year millions of dollars for the purchase of new aircraft for the Army and Navy and other millions through the Department of Commerce and the Post Office Department to promote the civil and commercial use of aircraft. The future of civil aviation is dependent upon the development of safer and more efficient types of aircraft. The increasing importance of aircraft for military and naval purposes makes it necessary that America have the most up-to-date and efficient aircraft. This means that America must keep abreast of other nations in the scientific development of the airplane.

It is not a matter of chance that at the present time the United States is at the forefront of progressive nations in the development of military and commercial aviation. It is the result of persistent and continuous research that has made it possible for American designers to develop aircraft of superior qualities.

I consider it a very serious matter to disturb the present status of the Committee as an independent establishment, as this status is largely responsible for its success. Any disturbance in status will affect adversely the efficiency of the organization and will undermine the very foundations of our aeronautical development.

The membership of the National Advisory Committee for Aeronautics includes seven governmental representatives from the War and Navy Departments, the Bureau of Standards, the Weather Bureau, and the Smithsonian Institution, and eight persons appointed from private life, all of whom serve as such without compensation. Its organization embraces eight principal committees and seven subcommittees, totaling 85 members, who also serve without compensation. It is evident, therefore, that this Committee represents the best thought of every group concerned with the technical development of aircraft.

I beg to assure you that I appreciate greatly your interest in the whole field of aeronautics and especially your interest in giving our Committee an opportunity to explain to you our point of view.

Sincerely yours,

JOSEPH S. AMES,
Chairman.

Encs.:
. . . "Some Reasons Why the National Advisory Committee for Aeronautics Should be Continued as an Independent Government Establishment."
"Some Comments on the Work of the National Advisory Committee for Aeronautics."

February 24, 1932.

SOME REASONS WHY THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS SHOULD BE CONTINUED AS AN INDEPENDENT GOVERNMENT ESTABLISHMENT

Reference: Current Suggestion to Transfer the National Advisory Committee for Aeronautics to the Department of Commerce and to Merge It with the Bureau of Standards.

1. The National Advisory Committee for Aeronautics is at present an independent Government establishment created by law in 1915, charged with the duty of supervising and directing the scientific study of the problems of flight. This function is extraneous to the major purpose of any other governmental agency.

2. The Committee is an effective agency for coordination and prevention of duplication in the field of aeronautical research. It is a recognized principle that coordinating agencies should be independent.

3. The Committee is a service agency, serving the needs of all governmental agencies concerned with aeronautics. It is a recognized principle that service agencies should be independent.

4. Military, naval, and commercial aviation are under the War, Navy, and Commerce Departments respectively. There can be no question that the technical activities of the Aeronautics Branch of the Department of Commerce and of its Bureau of Standards should be coordinated with those of the War and Navy Departments. The National Advisory Committee for Aeronautics could not continue to coordinate effectively the activities of the War, Navy, and Commerce Departments relating to aeronautical research if the Committee were under the control of either of those departments.

5. For the Advisory Committee to discharge its duties efficiently and deal fairly and impartially with technical matters it should remain an independent establishment.

6. The War, Navy, and Commerce Departments now have representation on the National Advisory Committee for Aeronautics. To place the Committee under the control of the Department of Commerce would give a dominating influence to its representative, would have the effect of denying equality to the other members, and ultimately would destroy the value of the Committee as an impartial coordinating agency.

7. The natural and certain consequence would be that the air services of the Army and Navy would cease to rely upon the Advisory Committee as they do now for the scientific study and solution of the more fundamental problems of flight, and would follow their own independent lines of endeavor, which would result in duplication, waste, and inefficiency and retard progress in military and naval aircraft development.

8. The Advisory Committee would cease to be a "national" advisory committee for aeronautics and would become merely an advisory committee for civil and commercial aeronautics under and for the Department of Commerce.

9. The Committee membership includes representatives from all governmental agencies concerned with the development of aeronautics and eminent scientists and aeronautical authorities from private life, including such men as Dr. Joseph S. Ames, President of Johns Hopkins University (Chairman); Dr. David W. Taylor, former Chief Constructor of the Navy (Vice Chairman); Dr. William F. Durand, of California, an eminent consulting engineer; Dr. Orville Wright, the inventor of the airplane; Honorable Edward P. Warner, former Assistant Secretary of the Navy for Aeronautics; Honorable William P. MacCracken, Jr., former Assistant Secretary of Commerce for Aeronautics; Honorable Harry F. Guggenheim, former President of the Daniel Guggenheim Fund for the Promotion of Aeronautics, Incorporated; and Colonel Charles A. Lindbergh. All the members serve as such without compensation. The dignity of membership on the Committee in its present status of an independent establishment and the satisfaction that comes from service rendered in a truly patriotic devotion to duty constitute the only compensation of the members. This made possible the fact expressed by President Coolidge in 1924 that "through this Committee the talent of America has been marshaled in the scientific study of the problems of flight, with the result that America occupies a position in the forefront of progressive nations in the technical development of aeronautics. The status of the Committee as an independent Government establishment has largely made possible its success."

10. To deny the Committee a continuance of its present independent status would inevitably lead to lowering of the caliber of its membership. The Committee could not long expect to hold the confidence of the Army and Navy air services nor exert the same healthy influence as in the past. The inevitable result would be the dissolution of the Committee and the loss to the nation of the organization which has been primarily

responsible for the leading position taken by America in connection with aeronautical research. This position must be maintained if we are to continue to be in advance of all other nations in the technical development of aircraft.

SOME COMMENTS ON THE WORK OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

"Through this committee the talent of America has been marshaled in the scientific study of the problems of flight, with the result that today America occupies a position in the forefront of progressive nations in the technical development of aeronautics. The status of the committee as an independent Government establishment has largely made possible its success."—Calvin Coolidge, President, U.S., The White House, Washington, D.C., Dec. 8, 1924, letter to Congress

Dwight W. Morrow, chairman of the President's Aircraft Board, in referring to the testimony presented at their Hearings said "—it is interesting to note that the aviation work of the Post Office Department and of the Advisory Committee for Aeronautics practically escaped all criticism."—Dwight W. Morrow (Letter to Dr. Ames Dec. 22, 1925)

". . . The National Advisory Committee is an excellent example of the way to accomplish results, that is to say, by a permanent body of men largely from within the service who know the work and who have authority. The Committee has accomplished real results not only in the coordination of the work of various Government branches interested in aeronautics, but in bringing them into closer contact with the public. The Committee's work has been of the greatest value in aiding and encouraging the aircraft industry."—Dr. S. W. Stratton, former Director of the Bureau of Standards, October 27, 1923

"Your reports every year are better and better in every way. They contain, in my opinion, scientific material of quite as high a value as anything produced at the National Physical Laboratory (British) or Göttingen (German aeronautical laboratory). They are infinitely clearer in presentation than any British reports. . . ."—New York University, Alexander Klemin, Professor of Aeronautics, April 4, 1924

". . . your committee is most helpful and authoritative. You are doing a great work and we in aviation all appreciate it."—Santa Barbara Aero Club, Earle Ovington, Commodore, Santa Barbara, California, November 24, 1926

". . . It is quite astonishing how fast and how accurately your published reports meet the needs of the field."—E. A. Briner, Consulting Engineer, East Orange, N.J.

". . . I received the Reports almost immediately, for which favor I would like to thank you very much. They contain such precious information that I wonder how I ever got along without them until now."—G. M. Bellanca, Aeronautical Engineer, Omaha, Nebraska, December 22, 1923

SOME COMMENT FROM THE AIRCRAFT INDUSTRY

". . . I wish to commend the very interesting work which you are doing, and to have you know that we sincerely appreciate the big part which you are playing in original research work which contributes so much to the development of aeronautics."—The Pratt and Whitney Aircraft Co., F. B. Rentschler, President, Hartford, Connecticut, December 19, 1925

". . . These reports are helpful to us beyond explanation. . . . Permit me through you to extend my appreciation for the great assistance in industry the Committee has been to us, and the gratitude of my organization for each and every one associated with the Committee."—Charles E. Lay, Commercial Aeronautical Engineering, Cincinnati, Ohio, January 12, 1925

". . . I have for the past year been a project engineer with the Lockheed Aircraft Corporation. The technical data I have received from the Committee have been invaluable to me. . . . the publications of the Committee constitute by far the greatest source of research data in this country, and no engineer who wishes to keep abreast of developments can afford to be without them."—Richard W. Palmer, Pasadena, California, February 3, 1930

". . . the conference was the most impressive and instructive one of this kind that I have ever had the privilege of attending, and you will be gratified to know that in our research work we have already been able to derive very definite advantage and assistance from the publications and work of your Committee."—Grover Loening, May 16, 1929

"I was very glad to receive the data on N.A.C.A. 2412 forwarded with your letter of the 7th. It came to hand at just the right moment; in fact, I was on the point of writing you a letter and asking you if I might not be supplied with this information. Another good example of the very efficient service rendered by the Committee."—Chance Vought Corporation, East Hartford, Connecticut, January 14, 1932

". . . In prosecuting this work I feel that the N.A.C.A. is making the biggest contribution that is possible in aviation at the present time, and the fact that the results of your work are made immediately available to the industry will do much to hasten the progress in aviation."—Packard Motor Car Company, J. G. Vincent, Vice President of Engineering, December 20, 1927

Your Committee is to be ". . . congratulated on the marvelous work done during the past year. I cannot help but feel that the Committee's new equipment and results achieved are among the outstanding achievements of the year in aeronautics. . . ."—Consolidated Aircraft Corporation, January 29, 1932

". . . Your work is of great assistance to us and is highly appreciated."—Pan American Airways, Inc., New York City, March 3, 1930

". . . We wish to take this opportunity of expressing to you our appreciation of the many courtesies extended to us by your Committee in the past. Your Reports and bulletins have been of the greatest assistance to us."—Amphibions, Incorporated, Garden City, N.Y., October 16, 1931

". . . Many thanks to you for the copy of Technical Note No. 219, 'The Comparison of Well-Known and New Wing Sections Tested in the Variable Density Wind Tunnel,' which I have just received. It is a very, very fine report and I want to congratulate you upon the way it is presented and the abundance of information contained therein. It is just another example of the good work that is carried on by the N.A.C.A. and we are getting so accustomed to the thoroughness of your reports that, naturally, we expect them all to be alike."—A. V. Verville, Buhl-Verville Aircraft Co., Detroit, Michigan, August 20, 1925

". . . I never before appreciated the great importance to aviation that the National Advisory Committee really is; the wonderful work that they are doing and the true interest that is shown in aviation by the results of their efforts. . . . the value to aviation of the research work which is represented in those volumes is immeasurable."—Skylark Airplane Co., Inc., Detroit, Michigan, May 5, 1927

28. "Economic Value of the National Advisory Committee for Aeronautics," Jan. 1933.

[The NACA maintained that its appropriations from Congress were cost-effective because its research resulted in savings to the armed services and to the American aviation industry. Nowhere was that argument more explicit than in this document, prepared when a move was afoot to transfer the NACA to the Department of Commerce.

NACA research unquestionably contributed to more efficient flight in the United States, but that fact does not guarantee the logic or the accuracy of the computations presented here. (The Committee was careful to label them *possible* savings.)

ECONOMIC VALUE OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

The conduct of fundamental scientific research in aeronautics by the National Advisory Committee for Aeronautics in one central Government laboratory, to meet the needs of all branches of aviation, is not a Governmental luxury that can be sacrificed. It is a necessity, vital for national defense because of its fundamental influence in enabling the Army and the Navy to keep abreast of other nations in the development of aircraft.

No money estimate can be placed on the immeasurable value of superior performance of aircraft in warfare, for aerial supremacy is quite likely to be ultimately decisive of a war; nor can a money estimate be placed on the indeterminable savings in life and property due to improved safety in the operation of both military and civil aircraft. The performance, efficiency and safety of aircraft of all types have been materially improved as a direct result of researches conducted by this Committee. The value in dollars and cents of improved efficiency in aircraft, however, can be estimated. Six researches completed within the last few years have been selected, which show that, when the results are applied to airplanes equal in number to those in use during the fiscal year 1932, savings in money alone will be made possible in excess annually of the total appropriations for the Committee for the eighteen years of its existence.

N.A.C.A. COWLING

In arriving at the estimated possible savings through the use of the N.A.C.A. cowling on all types of airplanes, the following factors were considered for each type of airplane in use in the United States for military, naval, and commercial purposes during the fiscal year ended June 30, 1932:

1. Actual hours flown; reduction in drag through use of cowling (at cruising speed); reduction in horsepower required through use of cowling for same cruising speed; reduction in initial cost of engine of less horsepower required; reduction in cost of airplane maintenance and operation resulting from saving in weight, including: Saving on depreciation; saving in insurance and interest charges on commercial airplanes and engines; saving on fuel and oil; and saving in maintenance costs of airplane and engine.
2. From the gross saving thus computed for each airplane in service there was deducted the cost of installation and maintenance of the N.A.C.A. cowling.
3. The remainder is the net saving per year for each airplane of a given type.

These factors applied to the airplanes in use in the United States by the Army, by the Navy, and by commercial operators, show estimated possible savings per year as follows:

Army	$1,686,800
Navy	1,286,600
Total, military savings	2,973,400
Commercial savings	2,325,900
Total annual savings from use of N.A.C.A. cowling	5,299,300

N.A.C.A. ENGINE-PROPELLER LOCATION

In arriving at the estimated possible savings through the use of the N.A.C.A. engine-propeller position in the wings of all types of multi-engine airplanes, the following factors were considered for each type of airplane in use in the United States for military, naval, and commercial purposes during the fiscal year ended June 30, 1932:

1. Actual hours flown.
2. Improvement in net efficiency due to use of N.A.C.A. engine propeller location.
3. Reduction in horsepower required at cruising speed.
4. Reduction in initial cost of engines of less horsepower required.
5. Reduction in cost of airplane maintenance and operation resulting from saving in weight, including:
    (a) Saving on depreciation.
    (b) Saving in insurance and interest charges on commercial airplanes and engines.
    (c) Saving on fuel and oil.
    (d) Saving in maintenance costs of airplane and engine.

These factors applied to the multi-engine airplanes in use in the United States by the Army, the Navy, and commercial operators, show estimated possible savings per year as follows:

Army	$702,200
Navy	342,500
Total military savings	1,044,700
Commercial savings	953,600
Total annual savings through use of N.A.C.A. engine-propeller position in multi-engine airplanes	1,998,300

TWO-STROKE-CYCLE ENGINE

The conventional type of gasoline engine is a four-stroke-cycle engine: that is to say, each piston makes two up-strokes and two down-strokes in delivering one power stroke. In the two-stroke-cycle engine, each down-stroke of a piston is a power stroke. Certain physical difficulties have existed, however, to delay the development of the two-stroke-cycle engine for general use in aircraft.

The N.A.C.A. has conducted researches for several years to solve these difficulties. It has made definite progress on the fundamental difficulties involved, as, for example, in the scavenging of burned gases from the cylinders and in the injection of fuel under pressure. The progress thus far made in the Committee's laboratory indicates that a two-stroke-cycle engine having compression ignition and fuel injection can now be built at an average weight of 1.4 pounds per horsepower as compared with the present average weight of 2 pounds per horsepower.

Total horsepower developed in Army, Navy, and commercial airplanes (hp)	413,725
At average of 2 pounds per horsepower for four-stroke-cycle engine (pounds)	827,450
At average of 1.4 pounds per horsepower for two-stroke-cycle engine (pounds)	579,215
Weight saved using two-stroke-cycle engine (pounds)	248,235
Multiplied by cost per year per pound of weight flown	$4.02
Annual possible saving	$997,905

EFFECT OF LOAD FACTOR RESEARCH ON WING DESIGN

By scientific investigations conducted by the National Advisory Committee for Aeronautics to determine the distribution of air loads imposed on airplane structures in flight, it is now possible so to design airplane wings as to give requisite strength with minimum weight.

For convenience in evaluating the saving thus made possible in the annual operating costs (disregarding savings in production costs), the single-engine commercial airplanes have been estimated at 5000 pounds each and multi-engine commercial airplanes at 15000 pounds each.

5,000-pound airplanes, 453 at 270 pounds saved per airplane (pounds)	123,000
15,000-pound airplanes, 199 at 610 pounds saved per airplane (pounds)	122,000
Gross weight saved on commercial airplanes operated in 1932 (pounds)	245,000
Annual saving at $4.02 per pound per annum	$984,900

USE OF N.A.C.A. 2415 AIRFOIL

Considering a typical cabin monoplane with N.A.C.A. 2415 wing installed in lieu of the previous conventional wing, there would be, at a cruising speed of 120 miles per hour, a reduction in total drag including wing and control surfaces of 17.28 pounds per airplane.

Cost per pound of drag per hour of flight		$.03½
Saving per hour of flight at 17.28 pounds drag saved per airplane		.60
Possible savings per annum at 60¢ per hour of flight per airplane, based on number of airplanes used during 1932:		
Army	$222,752	
Navy	148,647	
Total savings to Government	371,399	
Commercial savings	257,358	
Total savings per annum	$628,757	

OPERATION OF ENGINES WITH LARGE VALVE OVERLAP

The National Advisory Committee for Aeronautics through researches conducted at its laboratories at Langley Field, Virginia, has made possible an 18 percent increase in power of aircraft engines by using large valve overlap combined with fuel injection principle. Based on the aircraft engines in use in the United States during the fiscal year 1932, this principle makes possible an annual economic saving of $598,742, arrived at as follows:

Power saved (percent)	18
Total brake horsepower hours developed during year on aircraft engines of all types	413,724,750
Assuming liberal estimate of 1,000 hours' operation per year, the horsepower developed was (hp)	413,725
18% of above=horsepower saved (hp)	74,470
Equivalent weight saved at rate of 2 pounds per horsepower (lb)	148,940
Economic value of weight saved at $4.02 per pound per annum	$598,742

29. The Brookings Institution, "Memorandum on Report No. 12 on Senate Select Committee Making Recommendations Relative to National Advisory Committee for Aeronautics," 8 Nov. 1937.

[In 1937 the Brookings Institution analyzed the organization of the federal government at the request of the Senate Select Committee to Investigate Executive Agencies of Government. The goal was to suggest economies that could be effected through the elimination of duplication, a constant concern in Congress. Report No. 12 of the Institution recommended that the NACA be transferred to the Department of Commerce. This memorandum summarizes that report. Note that the efficiency and effectiveness of the NACA were never even brought into question, let alone studied; the recommendation turned entirely on general principles of organization. Congress failed to act on this recommendation, but the issues raised here remained a constant threat to the NACA's autonomy and independence.]

The staff of the Institute for Government Research has reviewed the analysis . . . and recommendations . . . contained in the section on air transportation and finds no basis for modifying the conclusions reached relative to the recommended transfer to the proposed Department of Transportation (the Transportation Section of the Department of Commerce) of the functions now performed by the National Advisory Committee for Aeronautics. The reasons for this conclusion are briefly set forth as follows:

The chief purpose of the reorganization study was to discover at what points and by what methods the functioning of the Executive branch of the government could be improved by the elimination of overlappings, duplications, and conflicts in authority and operation.

In the case of the National Advisory Committee for Aeronautics our analysis revealed a clear-cut case of duplication in the research work which this agency and the Bureau of Air Commerce are now authorized to carry on. Our recommendation that the work now done by the N.A.C.A. ". . . should be fitted into the general research program developed by the Department of Transportation in carrying out its air-transport promotional work. . ." was designed to eliminate this duplication. We made no analysis of the detailed functioning of the N.A.C.A., nor did we express any judgment relative to the quality of its work. The validity of our recommendation does not depend upon such analysis, for we did not suggest discontinuance of the function—merely its transfer from one agency to another.

Moreover, we discovered nothing in the general character of the work done by the NACA which would require that it be divorced from effective executive control in order to function properly. Its work is not in any way judicial or legislative in character. It can properly be performed (as is the case with similar basic research work carried on by the experimental stations of the Bureau of Public Roads) within the framework of the appropriate executive department.

Our recommendation was, therefore, based on the following considerations:

1. Two federal agencies, the Bureau of Air Commerce, and the National Advisory Committee for Aeronautics, are now authorized and instructed to carry on basic research work in the field of aeronautics.

2. One of these agencies, the Bureau of Air Commerce, is in addition charged with primary responsibility for the promotion and regulation of air commerce in furtherance of the declared policy of Congress to build and maintain a safe, adequate, economical, and efficient air transport system, designed

(a) To meet the reasonable needs of the American people for air transportation;

(b) To supply reasonable air mail service;

(c) To make available an air craft manufacturing industry capable of expansion in time of national emergency to meet the military needs of the country; and

(d) To insure the expeditious development of miscellaneous flying.

3. Basic research in the fundamental problems of flying, the physical characteristics of materials and operating equipment, etc., must be carried out by the Bureau of Air Commerce in order to discharge its statutory responsibilities.

4. The work now done by the NACA is neither judicial nor legislative in character and consequently does not require independent organizational status.

5. Its present status is explained largely by historical factors.

All of those points might have been elaborated in the transportation report. Such elaboration applied consistently to analysis of the 21 major federal agencies engaged in activities affecting transportation obviously would have extended unduly this section of the report. We did, however, indicate briefly:

1. That between 1915 and 1926 the federal government's activities in the field of aeronautics were based almost exclusively upon military considerations . . .;

2. That the NACA was created in 1915 as a part of this limited program . . .;

3. That beginning with the Air Commerce Act of 1926 congressional policy has progressively shifted in emphasis from the military to the economic aspects of air transportation . . .;

4. That the work of the NACA has not been limited to its original major purpose—basic research in aeronautics designed to serve military purposes—but has followed the trends in the development of air transportation generally. This observation is supported by the committee's stated objectives of its research work: " . . . (1) to coordinate the research needs of aviation, civil and military; (2) to define the problem to be investigated; (3) to allocate the problems to prevent overlapping and duplication; (4) to anticipate research needs; (5) to organize and conduct at one central governmental service laboratory (Langley Field) scientific research on the more fundamental problems of flight, and especially those problems requested by the Army, Navy, and the Bureau of Air Commerce; (6) to disseminate resulting new knowledge; (7) to pass upon technical merits of aeronautical inventions; and (8) to conduct specific investigations for and at the expense of the aircraft industry when adequate facilities are not elsewhere available.". . .;

5. Under the terms of the Air Commerce Act of 1926 and amendments the Bureau of Air Commerce is instructed among other things to " . . . 'study the possibilities for development of air commerce and the aeronautical industry and trade in the United States, and to collect and disseminate information relative thereto' . . . 'to advise with the Bureau of Standards and other agencies in the executive branch of the Government in carrying forward such research and development work as tends to create improved air navigation facilities.' . . ."

Such research work is essential to the formulation of technical rules regarding equipment, flying, landing, the determination of responsibility for air accidents, etc., with which the Bureau of Air Commerce is charged. . . .

Consideration has been given to the question whether the fact that the N.A.C.A. as originally set up was concerned largely with questions of national defense does not indicate that it should be preserved as a separate agency independent of any department. We do not think this is the case for the following reasons: (1) As already indicated, the work of the N.A.C.A. has been steadily broadened to include other than military aspects of the problem; and (2) the Bureau of Air Commerce has been established to deal with problems of national defense as well as air transportation generally. The logic of the situation clearly calls for the consolidation of these agencies in the interests of economy.

Assuming the accuracy of our analysis of the functions of the National Advisory Committee for Aeronautics and since we failed to discover any compelling reason why its present work could not be effectively performed by the Bureau of Air Commerce (or whatever agency might be designated to administer the general air transportation policy of the government) our recommended transfer of the N.A.C.A. to the Bureau is essential to the preservation of the internal consistency of the report as a whole. The Bureau of Public Roads, for example, has for years carried on basic research work in the strength of materials, subsoil conditions, stresses and strains upon materials, etc., as an integral part of its administration of the federal aid acts. These research activities are equally as fundamental to the proper administration of the federal aid acts as are analogous research activities to the effective administration of air transport legislation. Both have their military implications. If convincing reasons can be found for the severance of fundamental research policy from the administration of general air transport, we would have been compelled for the sake of consistency to recommend transfer of the fundamental highway research now carried on by the Bureau of Public Roads, to an independent organization. We discovered no justification for such a recommendation, nor did we find any basically distinguishing features which would require that one phase of the research function should be carried on by a department, and the other by a semi-official organization, financed with federal funds, but divorced from any effective control of the government unit charged by Congress with responsibility for administration of the federal government's air navigation program.

30. Westover Committee Report, 19 Aug. 1938.

[Shortly before his death, Maj. Gen. Oscar Westover joined two other members of the NACA in an attempt to formulate a policy to govern the NACA in the event of war. Their report laid down the principles endorsed by President Roosevelt the following year and implemented in World War II. Although this policy solved many problems for the NACA, it left the deferring of NACA personnel from military service to be worked out slowly and painfully during the war.]

Subject: Relation of the National Advisory Committee for Aeronautics to National Defense in Time of War.

To: Chairman, National Advisory Committee for Aeronautics.

1. The committee appointed for the purpose of considering the study covering the relation of the National Advisory Committee for Aeronautics to National Defense in Time of War . . . finds that the questions contained therein can be resolved into the following elements:

a. What is the present status of the NACA in regard to National Defense?

b. (1) What should be the status and relation of the NACA to National Defense in a national emergency? (2) Where does it fit into the scheme for National Defense?

c. What should be the status of the personnel of the NACA during a national emergency?

d. How should the NACA obtain additional personnel, if needed for expansion, in time of an emergency?

2. With reference to the questions listed in Paragraph 1, above, the following remarks are made:

Q. a. What is the present status of the NACA in regard to National Defense?

A. Peace Status. The NACA is a Federal agency, with a mission prescribed by law. It performs essential work for the Army, the Navy, other Federal agencies, and for the Aeronautical Industry.

Q. b. What should be the status and relation of the NACA to National Defense in a national emergency? (2) Where does it fit into the scheme for National Defense?

A. War Status.

(1) The status of the NACA in a national emergency has not been fixed. The services of the NACA are deemed to be essential to National Defense for the successful prosecution of a war.

(2) The NACA can properly submit recommendations to higher authority as to its proper place in the scheme for National Defense. These recommendations could be that—

(a) The NACA continue to function as a separate entity, the same as it does in peace. In this connection, a mobilization plan should be prepared and submitted to the President for approval. Such action would place the NACA in the category of an Independent Establishment, Board, or Commission . . .; also, on a parity with the Armed Forces in case of an emergency, rather than as an integral part thereof. The degree of coordination and cooperation between the NACA and the agencies which would have paramount need for the services of the NACA should be given careful consideration. The Armed Forces will, undoubtedly, desire a more definite status for the NACA than one based upon coordination and cooperation.

(b) The NACA become an adjunct of The Aeronautical Board. The Aeronautical Board is a continuing Joint Board. . . . Since the NACA upon the declaration of a national emergency would, undoubtedly, confine its activities to aeronautical matters and since such aeronautical matters jointly concern the War and Navy Departments and are handled by the Aeronautical Board, the services and resources of the NACA could well be utilized by this Joint Board. Such a position would make the NACA a part of the Armed Forces, and, on one hand, would permit direct collaboration and/or action between the NACA and the Chief of the Air Corps and the Secretary of War; on the other hand, the Chief of the Bureau of Aeronautics and the Secretary of the Navy. It is realized that such action would place the NACA, for the period of the emergency, in a more subordinate position than that which it now enjoys; however, in the interests of National Defense, this is believed to be a logical plan.

An effort to definitely place the NACA in such a position in the scheme for National Defense is shown in . . . [a] proposed Mobilization Plan for The Aeronautical Board. That portion of this Mobilization Plan which pertains to The Aeronautical Board proper was drawn up by a subcommittee of that Board and has not, as yet, received the approval of The Aeronautical Board. It is realized that the submission of Section 3 of this plan to The Aeronautical Board would be only as a recommendation as to the line of action which would be acceptable to the NACA and that the final Mobilization Plan would be drawn up by The Aeronautical Board and submitted to the NACA for its comment, or approval, prior to submission thereof to higher authority.

Q. c. What should be the status of the personnel of the NACA during a national emergency?

A. The committee at present consists of military and civilian personnel. No cogent reasons can be advanced which would require a change to a military status for such members in time of an emergency. It is believed that no advantage would be conferred, by a military status, upon the personnel employed by the NACA, either in its Washington offices or in the Langley Memorial Aeronautical Laboratory at Langley Field, Virginia. A civilian status for such personnel will, undoubtedly, meet with military approval as the granting of military rank to personnel engaged upon quasi-military work as was done during the World War is not now believed to be desirable.

Q. d. How should the NACA obtain additional personnel, if needed for expansion, in time of an emergency?

A. The answer to this question is dependent upon the decision adopted by the Committee as to where the NACA should be placed in the scheme for National Defense; for instance—

(1) If the NACA is to remain a separate entity, then it would include in its Mobilization Plan suitable paragraphs on the subject of personnel.

(2) If the NACA is to become an essential adjunct of The Aeronautical Board, then the Aeronautical Board in its Mobilization Plan should provide for the necessary personnel to properly carry on the activities of the NACA. . . .

3. In connection with this study, the question of "blanket deferment" for NACA personnel was raised, and it is believed that no time or thought should be given to this question as it is not considered to be possible of attainment—the American Legion is definitely opposed to the granting of "blanket deferment" to any industry or class of personnel. The solution recommended is as follows:

a. The case of each individual employee must be considered on merit, when war is imminent, due regard being given to the qualifications, position held, and the recommendations of the management (NACA) as to the need for the services of the individual concerned.

b. The attitude of the War Department on this matter in the past is believed to be essentially as follows:

(1) No attempt has been made to place restrictions on appointments of Reservists from either allocated or unallocated facilities.

(2) It has not been the policy to deny an Army Reserve commission to an applicant merely because he may be employed by an allocated facility. It is true that the effect on industry by sudden withdrawal for war service of employees who hold Reserve commissions has caused some concern, but, because of the many considerations involved, it has not been thought practicable to attempt to apply a restriction to Army Reserve officers based on whether they could or could not be spared by their employers without grave detriment to essential war production. A principal hindrance to such a classification is the fact that a Reserve officer's status and occupation in civil life may change frequently. Each case must be considered on its merits, when war is imminent, due regard being given to the qualifications, position held, and the recommendations of the management as to the need for the services of the individual concerned.

(3) It must be realized that certain deferments will have to be made in order to be able to supply munitions to the fighting forces and avoid the necessity for wholesale exemptions. To the end that this may be accomplished the matter is now under study and it is believed possible to work out detailed plans to apply in every instance that will serve to minimize interference with essential war production and at the same time not deny to the Armed Forces the use of such men as may be particularly fitted and necessary for the military and naval services.

4. The committee recommends that:

a. The NACA seek a place in the scheme for National Defense as an essential adjunct of The Aeronautical Board for the duration of a national emergency only.

b. The personnel employed by the NACA continue on a civilian status after the outbreak of an emergency.

c. The question of "blanket deferment" for such personnel not be raised as a satisfactory solution can be obtained by other means.

d. No restrictions or objections be made to personnel of the NACA accepting commissions with the military forces in time of peace; however, due notice to be given the military forces that the NACA is an "Essential Industry" and requests for "individual deferments" must be expected by the military forces.

(s) O. WESTOVER,
Major General, Air Corps, Chief of the Air Corps, Chairman.
(s) A. B. COOK,
Rear Admiral, U.S. Navy, Chief, Bureau of Aeronautics, Member.
(s) W. R. GREGG,
Chief of Weather Bureau, Department of Agriculture, Member.

31. H. H. Arnold to George W. Lewis, 5 Jan. 1939, enclosing "Discussion of a Proposal to Establish an Aeronautical Laboratory for Applied Research."

[Late in 1938, Clark B. Millikan of the California Institute of Technology suggested to H. H. Arnold, Chief of the Army Air Corps, that the government fund an applied aeronautical research laboratory at Caltech as a national defense measure. In his formal proposal he chose to identify two kinds of aeronautical research, basic and applied. When Arnold forwarded the proposal to the NACA for comment, he added a third kind, production research. Commenting on this correspondence, John Victory proposed still another formulation of the division of research (see document 32). Between the lines of Millikan's proposal can be seen implied criticisms of the NACA, an attempt by Caltech to do on the west coast what the NACA was doing at Langley, and a catalyst for the NACA to build its own laboratory in California.]

Dear Dr. Lewis:

During a recent trip to the West Coast, Dr. Millikan brought up the subject of Government sponsorship of aeronautical research activities and its relationship to the National Defense. While the enclosed proposal is pertinent to the procurement of military aircraft, it is a matter which properly falls directly within the authority and responsibility of the N.A.C.A.

It is the opinion of the undersigned that aeronautical research activities should be divided as follows:

(1) *Basic Research.* The N.A.C.A. to be directly responsible for the correlation and coordination of all basic research conducted by Governmental establishments. To coordinate research and development activities in the fields of Applied Research and Production Research, which in so many instances will suggest new problems for basic research.

(2) *Applied Research.* The Army and Navy to be directly responsible for the coordination and immediate application of new aerodynamic theories, principles, and discoveries to the particular problems of military aircraft. This involves close cooperation between Wright Field, the Naval Aircraft Factory, and engineering staffs of the aircraft factories.

(3) *Production Research.* The engineering staffs of the various aircraft factories to be responsible for the conduct of the various aerodynamic tests and experimentation that is connected with the successful completion and production of military aircraft. This Production Research to be conducted in the facilities available at Universities or other private or civilian institutions in the vicinity of the manufacturer concerned.

Plans for new facilities at Wright Field will be coordinated with the N.A.C.A. with a view of making it possible to eliminate Basic Research from the Wright Field aerodynamic experimental programs.

Since there is no definite line of demarcation between the characteristics of a Basic Research tunnel and one primarily designed for Applied Research, there is bound to be some overlapping between the aerodynamic research facilities of the N.A.C.A., Wright Field, the Naval Aircraft Factory, and Educational Institutions, which indicates quite definitely the necessity for coordination of all activities by the N.A.C.A.

With the above in mind and with the idea that your organization should be the coordinating agency, the enclosed project from the California Institute of Technology is forwarded for such action as is necessary. In the opinion of the undersigned there is a need for additional Production Research facilities on the West Coast for the use of the aircraft industry. These additional facilities are in excess of any which the N.A.C.A. may find necessary to construct to carry on its own functions.

Sincerely yours,

H. H. ARNOLD,
Major General, Air Corps, Chief of the Air Corps.

DISCUSSION OF A PROPOSAL TO ESTABLISH AN AERONAUTICAL LABORATORY FOR APPLIED RESEARCH

Introduction

The great expansion in the United States Air Services, which is now under discussion as a national defense measure, will require a corresponding enlargement in the country's aeronautical research facilities. Research in aeronautics can be divided into two categories, which may be described by the adjectives "basic" and "applied." The former is concerned with fundamental problems not associated with any specific aircraft design, while the latter deals with questions arising in the development and design of a particular machine. The two categories are far from unrelated and must be developed together in order that research activities may have anything like their maximum possible efficiency. The following discussion treats certain aspects of the question of applied research in aerodynamics, but the latter's connection with the basic field will often appear.

The fundamental tool for experimental applied research in aerodynamics is the wind tunnel, and it seems very certain that the wind tunnel's importance in this connection will increase rather than diminish in the future. It, therefore, appears that an immediate consequence of any considerable aeronautical expansion will be the necessity for an increase in the wind tunnel facilities available for applied research.

Characteristics of an Applied Research Wind Tunnel

There are certain characteristics which wind-tunnel testing in connection with applied research should possess, but which may not be essential to basic research investigations.

a) The tests must be rapidly made and the results be immediately available.

b) Changes and modifications to the models must be relatively simple to make.

c) It must be possible to decide on modifications and further tests in the light of data just obtained, and without delaying the testing.

d) The Reynolds number must be large enough so that critical points do not occur between the test and full-scale values.

e) The models must be large enough to permit the accurate reproduction of important details, but small enough so that their expense is not excessive. . . .

It appears that a new wind tunnel, designed primarily for applied research in connection with airplane designers and manufacturers, should have approximately the following characteristics in order to make the most effective possible contribution to airplane design: It should be a closed-return type with a working section about 12 feet in diameter, with an operating speed of about 400 m.p.h. at normal density, and should be capable of being partially evacuated so as to permit the attainment of maximum speeds of the order of 600 m.p.h. It must also have the features listed under a) to e) at the beginning of this section.

Desirability of Some Decentralization of Applied Research in Aerodynamics

There are many factors which lead to the conclusion that a certain amount of decentralization is desirable in connection with research work of the type in question. Requirements a), b), and c) of the previous section indicate the importance of close cooperation and contact between a manufacturer whose design is undergoing tests and the testing personnel of the wind-tunnel agency. Such contact is enormously facilitated if the factory and laboratory are reasonably near one another. Since the aircraft industry in the United States, to a very large extent, located in several well-defined but widely separated regions, a number of applied research centers is immediately indicated. The flexibility in testing procedure, which is essential to satisfactory cooperation in industrial wind-tunnel testing, is also much easier to maintain in a relatively small laboratory than in a great central research establishment.

In any such expansion as is currently being considered, the central governmental research organizations, such as the N.A.C.A. and the Army station at Wright Field, would, of course, be very largely increased in size. There are, however, limits to the amount of expansion which can efficiently be carried out with any organization in a short time. Above these limits such an expansion is most effectively accomplished through subdivision and the development of separate units.

Such a subdivision might even be carried to the extreme in which each factory maintained its own laboratory and wind tunnel in which all of its individual research work was done. This, however, would be highly undesirable. In the first place, a laboratory capable of dealing adequately with most of the designers' problems would involve far too much capital investment for any one company. Furthermore, a single company could not make enough use of the required elaborate equipment to justify its cost. There are many cooperative investigations which fall into the category of basic research, but which are of importance to several companies at the same time. Such investigations can be carried out much more satisfactorily by an independent than by a company laboratory.

The combination of basic and applied research, which can be effectively handled by an independent research organization working in close cooperation with manufacturers' engineers, furnishes a powerful argument in favor of this type of laboratory. It very frequently happens that interesting and important basic research problems are suggested during a more or less routine industrial test. Such problems often do not come to the attention of pure research workers, and they can almost never be pursued in a company laboratory. They can, however, be readily incorporated into the basic research program which an independent research laboratory would normally be engaged upon as a background for its applied research activities.

Coordination is, of course, a very important element in the efficient progress of research. However, it has often been demonstrated that coordination can be very satisfactorily attained between several laboratories, even though they are at large distances from one another. On the other hand, very great advantages are derived from the stimulus of friendly competition between such laboratories. The greatest advances, not only in experimental technique but also in the development of new ideas, very frequently occur when several groups are attacking the same type of problem more or less independently.

In view of the above remarks, it is interesting to note the methods adopted by the Germans in their recent remarkable expansion in aeronautical research. The central government agency, the D.V.L.,* was greatly enlarged, and this indeed was the most striking feature of their program. However, another extremely important and carefully worked out element was the setting up of five elaborately equipped research establish-

*Deutsche Versuchsanstalt für Luftfahrt (German Aeronautical Research Establishment) ments at the leading centers of higher technical education throughout the country. Each of these establishments, under the direction of one of the local professors, functions as an independent research laboratory, although the activities of all are correlated through the Air Ministry. A study of the recent issues of the Air Ministry's publications *Luftfahrtforschung*, shows that this type of organization has already proved remarkably fruitful, as indicated by only the published output from these independent laboratories.

Desirability of Locating an Applied Research Laboratory at the California Institute of Technology

At the present time, approximately 50% of all the airplane building of the country is carried out in a relatively small region in Southern California. Practically all of the wind-tunnel testing associated with the development of this great industry has been done in the ten-foot wind tunnel of the Guggenheim Aeronautics Laboratory at the California Institute of Technology (hereafter referred to as GALCIT). When this laboratory was constructed in 1928, it was planned that the time of the wind tunnel should be about equally divided between basic research and applied research or industrial testing. However, the demands of the industry have been so overwhelming that during the past several years it has been necessary to operate the wind tunnel 15 to 16 hours per day with two complete shifts of workers, and only 16% of its time has been available for basic research problems. It is clear that the existing facilities are sorely overtaxed and that any further expansion of the industry will make an enlargement of research equipment and staff essential.

A brief resumé of the applied research activities of the wind tunnel over the eight-year period of its operation to date will indicate something of the scope of its work. A total of 138 reports has been prepared, covering separate investigations for manufacturers on 50 completely distinct models. Many of these models were tested several times in modified forms, the later modifications being suggested by the results of the previous wind-tunnel tests. Of these reports approximately 60% dealt with military or naval models, while the remaining 40% were concerned with commercial aircraft. The investigations were conducted for eighteen different companies, five major firms accounting for a very large majority of all the tests. As mentioned above, the tunnel has been operated with two shifts of workers for the past several years, during which period its testing facilities have usually been reserved for two to three months in advance. In addition to this industrial testing, a large number of basic researches has been carried on, particularly in the earlier years before the wind-tunnel congestion became so severe.

The organization which has been developed as a result of the experience gained in this work is a somewhat unusual one. The industrial testing is under the direction of one of the members of the California Institute staff, whose applied research activities are considered as separate from his academic ones. He is assisted by two other members of the academic staff who are part-time members of the wind-tunnel group. Three permanent technical assistants are also included in the organization. A considerable proportion of the actual running of the tunnel is done by postgraduate aeronautical students of American citizenship. All members of this group are pledged to secrecy regarding industrial testing and are required to have no affiliations with any aircraft company. Since 1930 the California Institute has awarded 141 degrees for postgraduate work in aeronautics. A considerable proportion of all the United States citizens represented in this list has worked for one or more years on the wind-tunnel staff. It is felt that the training thus received has been extremely valuable to these men in their later careers as aeronautical engineers. In case of a large expansion in aeronautics, one of the vital problems will be the adequate training of a sufficient number of engineers, and such an arrangement as that just outlined should be of considerable assistance in supplying this need.

Summarizing the above discussion, it would appear that a modern applied research laboratory located at the California Institute of Technology could be of great service in view of the following points:

1) The great concentration of aeronautical industry in Southern California, far removed from the government research centers in the east.

2) The proven demand for such a laboratory, for which the existing facilities are very inadequate under present conditions. Hence even a moderate expansion of the local industry would make a material enlargement in the applied research facilities essential.

3) The very considerable experience of the GALCIT wind-tunnel staff in the field of applied research, and the close connections already developed between it and the airplane industry.

4) The possibility of effectively combining industrial testing with basic research, which would be afforded by the present equipment and staff of the GALCIT.

5) The procedure already developed at the GALCIT for giving advanced American students valuable experience through industrial testing, in their training as aeronautical engineers.

Specific Proposal for an Applied Research Laboratory

In the light of the preceding discussion, the following proposal is suggested as solving one of the problems raised by any considerable expansion in the United States air force:

1) To establish, as a national defense measure, an aerodynamical applied research laboratory at the California Institute of Technology, under the direction of one or more of the departments of the United States government, such as the War Department, the Navy Department, and the Civil Aeronautics Authority.

2) The primary purpose of this laboratory would be to carry out tests for manufacturers engaged in producing airplanes for the government.

3) The chief element in the laboratory would be a very modern wind tunnel, whose characteristics would be such as to permit the investigation of the major aerodynamic problems which can be expected to arise in the near future.

4) The laboratory would work in close cooperation with the N.A.C.A., Wright Field, and the other governmental research agencies concerned with aeronautics.

5) The details of organization and administration need not be discussed in this preliminary memorandum. It should, however, be pointed out that a somewhat similar cooperative arrangement between the California Institute and the U.S. Department of Agriculture has been carried on very successfully during the past two years in connection with the latter's "Cooperative Laboratory, Soil Conservation Service, California Institute of Technology."

The approximate characteristics of the wind tunnel which is suggested as satisfying the anticipated requirements are as follows:

Type—Single-return, closed working section, capable of compression up to 4 atmospheres or evacuation to ¼ atmosphere, circular cross section throughout.

Dimensions—Working section diameter = 12 ft.; Working section length = 18 ft.; Contraction ratio = 4; Overall length = 135 ft.; Fan diameter = 18 ft.

Construction—Welded ½-in. steel plate, water cooling on surface and vanes.

Power—Two 4000 h.p. A.C. motors driving oppositely rotating propeller-type fans with adjustable pitch blades. The motors are designed for short-period operation at 50% overload.

Approximate Performance (with motors operating at 50% overload of their rated power):
Maximum speed at ¼ atmosphere pressure = 630 m.p.h.
Maximum speed at 1 atmosphere pressure = 415 m.p.h.

Maximum speed at 4 atmosphere pressure=260 m.p.h.

Maximum Reynolds number at 4 atmospheres pressure with aspect ratio 6 model and moderate tunnel wall corrections=16.5×10^6.

A preliminary analysis leads to the following estimate of the probable costs of the wind tunnel, the necessary associated equipment, and the building required to house them:

Tunnel structure, electric drive, cooling system	$420,000
Balance systems, shop facilities, associated research equipment	165,000
Building (heating, ventilating, furniture)	200,000
Total	785,000

32. Memorandum, John F. Victory to Dr. Lewis, "General Arnold's letter of January 5, 1939, re basic research, applied research, and production research," 9 Jan. 1939.

[The NACA always tried to define its research in such a way as to render it unique in the United States, duplicating no other agency or institution. In this rebuttal to document 31, John Victory displays some of the defensiveness and sophistry that crept into these claims. Aeronautical research is simply too complicated to be compartmentalized as neatly as NACA management might have wished.]

1. The National Advisory Committee for Aeronautics conducts scientific research in aeronautics, including basic research and applied research. The law provides that it shall be the duty of the Committee "to supervise and direct the scientific study of the problems of flight with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions." The law also authorizes the Committee to "direct and conduct research and experiment in aeronautics."

2. It is the policy of this administration, as it has been of previous administrations, to avoid and prevent unnecessary overlapping and duplication in the Government activities. In the field of aeronautical research this responsibility devolves upon the Committee.

3. An analysis of the activities of the Committee at its Langley Field laboratories indicates that the major portion—approximately 70 percent—of its work has been scientific investigations undertaken at the request of either the Army or the Navy to meet present needs. Aside from the inherent and insuperable difficulty of drawing a clear line of distinction between basic research and applied research, both of which are now conducted and coordinated by the Committee without overlapping or duplication, it appears quite clear that if the Committee were to be limited to so-called basic research, so much would remain undone that is necessary to meet the needs of military, naval, and commercial aviation, that there would inevitably ensue overlapping and duplication by the governmental agencies concerned in the field of so-called applied research—all at the taxpayers' expense.

4. As a substitute for the basis of clarification of functions proposed by General Arnold, the following outline is suggested:

(1) *Scientific Laboratory Research.* The functions of the N.A.C.A. include the supervision, direction, and conduct of scientific laboratory research in aeronautics;

the coordination of the research needs of aviation, civil and military, including the problems of the industry, to prevent unnecessary overlapping and duplication; and the coordination and effective stimulation and support of aeronautical research in educational and scientific institutions.

(2) *Military Experimental Engineering.* The Army and Navy are directly responsible for the immediate application of the results of scientific laboratory research conducted by or under the cognizance of the N.A.C.A., and bring their research needs to the attention of the Committee; the Army and the Navy conduct experimental engineering and development work necessary to meet their needs in connection with the design and development of military and naval aircraft and equipment; the Army and the Navy conduct necessary research in any branch of aeronautics for which the N.A.C.A. has no facilities or inadequate facilities—any such research activities being coordinated through the N.A.C.A. subcommittees so as to increase if possible the value of the results and also to avoid unnecessary overlapping or duplication of effort.

(3) *Industrial Experimentation and Development.* The engineering staffs of the various aircraft and engine factories are to be encouraged to conduct industrial research, tests, and experiments connected with the successful design and production of aircraft; to have access to the enlarged facilities of the N.A.C.A. for the conduct of any wind-tunnel investigation connected with military or naval aircraft; and to have similar access to the use of the Committee's facilities for the solution of any other problem whenever adequate facilities are not existent or available at the wind tunnels of educational institutions.

J. F. VICTORY,
Secretary.

33. Jerome C. Hunsaker, "Memorandum on Postwar Research Policy for NACA," 27 July 1944.

[World War II brought a dramatic rise in the size, power, and influence of the American aviation industry, especially of aircraft manufacturers. It also brought into positions of power in the NACA not only industry representatives, but also new officers sympathetic to industry demands for a larger voice in NACA affairs. As NACA Chairman Jerome Hunsaker began considering a postwar research policy for the NACA, he actively sought the opinions of industry representatives. This memorandum summarizes discussions he had during a cross-country trip in mid-1944. Evolution of these comments into a NACA policy can be traced in documents 34 through 36.]

1. The conferences with leaders of the Industry in May and June were frankly exploratory but did, in my opinion, develop general agreement among Industry representatives on the following points:

(a) NACA should in the postwar period concentrate on fundamental research to advance the aeronautical sciences.

(b) Research reports should eventually be published, but the American industry should be given the results a year or so ahead of foreign competitors.

(c) NACA should not develop specific products or designs, except as necessary to demonstrate a principle or to prove an application.

(d) NACA should investigate the products of industry as requested by government agencies and in this connection do such analysis and development work as may be necessary to overcome defects or to make improvements.

(e) NACA should avoid establishment of facilities for research in those fields where industry is well equipped, i.e., radio, metallurgy, chemistry, fuel technology, etc.

2. On the following points, difference of opinion seemed to prevail:

(a) Whether or not NACA should allow the use of its facilities for the testing (and development) for industry of specific products. The present policy of the NACA concerning the use of its facilities for investigations for the industry of specific products is summarized as follows:

The work desired must relate to aeronautics; must necessarily involve the use of NACA facilities, i.e., adequate facilities not available elsewhere; work is paid for by firm, and results are its exclusive property against remainder of industry, but are available for use of the government.

The larger units of industry may be expected to be in opposition to the smaller plants having access to the use of NACA facilities.

The question is, "In the postwar period should the NACA adhere to this policy?"

(b) In the discussion at Cleveland with the representatives of the industry, there was considerable discussion about the sharing of public funds available for development. The industry inferred that it can use such funds to better advantage than government laboratories in developing specific products and at the same time strengthen their own organizations.

(c) Whether or not the Cleveland laboratory constitutes a potential threat to the engine industry. (The idea here is that private enterprise has already developed very superior engines and fuels and does not need government competition in research, invention, and development.)

3. There is undoubtedly some misconception on the part of representatives of the industry as to aeronautical research versus aeronautical development. The Committee's laboratories in the postwar period would be concerned primarily with aeronautical research. The discussion noted above had to do primarily with engine research. It was recognized in discussion by the members of the Committee that there is a certain overlapping between the fields of research and development.

4. While difference of opinion can be expected, it is fair to state that engineers from industry show no reluctance to use NACA facilities and advice, and their companies express appreciation for NACA help in no uncertain terms. Doubts as to the future role of NACA come from the heads of some of these same companies. My own feeling is that such doubts are based on these factors:

(a) Realization that, with NACA research results and test facilities available to all, the best engineering organizations in the engine field may lose a competitive advantage won by their own enterprise.

(b) Observation that Cleveland seems to be concentrating on the development of one make of liquid-cooled engine to improve its performance.

(c) Observation that NACA is leading jet-propulsion and gas-turbine developments in collaboration with firms previously outside the aeronautical engine field.

(d) Observation that current wartime NACA research activities are largely of a developmental character, which the larger units of the industry can themselves handle when they have a surplus of engineering manpower.

5. It is necessary that the Committee consider its future policy primarily in the light of what the War, Navy, and Commerce Departments plan to do. In particular, our postwar policy should take cognizance of the following changes in the distribution of research and testing facilities since 1940:

(a) Extensive wind-tunnel and engine-testing facilities at Wright Field

(b) Additional Navy facilities at Carderock, Philadelphia, and Patuxent

(c) Wind-tunnel facilities at Curtiss-Wright, Pratt and Whitney, Boeing, California Institute of Technology, North American, and Lockheed

(d) Power-plant facilities at Pratt and Whitney, Wright Aeronautical, Allison, General Electric, Westinghouse, and Allis-Chalmers, and proposed Packard engine-test facilities at Toledo

(e) A strong engineering organization in the C.A.A.,* both in Washington and in the field

(f) Extensive facilities in the fields of aviation physiology, meteorology, metallurgy, radio and armament

6. I believe that when the war pressure from the Army and Navy is relaxed the NACA should revert to its prewar policy of concentrating on fundamental research which it will be free to do to a greater extent than before the war because of the existence of so many new test facilities in the Army, Navy, and industry.

7. In the preparation of estimates for the fiscal year 1946, the Bureau of the Budget has requested four estimates: the first based on continuation of the war in Europe and in the Orient during the fiscal year 1946; the second on the termination of the war in Europe by July 1, 1945 and continuation of the war with Japan; the third on the continuation of the war in Europe and the end of the war with Japan by July 1, 1945; and the fourth on the termination of both wars by July 1, 1945.

In the preparation of these several estimates, plans will be made for curtailment of staff under the contingency that both wars will be over by July 1, 1945, and placing of certain facilities in stand-by condition as the Army and Navy development projects decrease. In preparing these estimates it will be necessary to have a list of Army and Navy research authorizations on which work should continue and a list of research projects of a fundamental character with particular reference to the development of civil aviation, which would be initiated by the NACA upon the termination of the war. Such estimates will include the backlog of fundamental research neglected during the war period.

J. C. HUNSAKER.

34. "Notes on discussion at meeting of NACA, July 27, 1944," 8 Aug. 1944.

[When the NACA Executive Committee discussed Chairman Jerome Hunsaker's memorandum on postwar research policy (document 33) none of the industry members were present. All the government members displayed a familiarity with—and some sympathy for—industry views on government research in aeronautics, especially on the vague and shifting line between research and development. But many seemed to share Vannevar Bush's feeling that the industry, especially the engine manufacturers, had not yet earned the concessions they were demanding of the government. All those participating in this discussion were members of the Main Committee; their full names and titles are listed in App. B.]

Significant discussion noted as follows:

1. "(a) NACA should in the postwar period concentrate on fundamental research to advance the aeronautical sciences."

Dr. Bush: Observed that in the aircraft industry there are two groups, those building for the Army and Navy and those building for the general public.

General Echols: Said the NACA should not adopt a policy ruling it out of doing things it ought to do. We should have some policy expressing intent that the NACA will confine itself to fundamental research. The Services will handle applied

*Civil Aeronautics Administration.

research and development to the extent practicable and pass some of those problems on to the industry. They are convinced the NACA wants big appropriations to put them out of business. They are also afraid the Government will operate all the Goverment-owned plants. It would be very helpful to get that fear out of their minds. It would be well to have a Governmental expression of intent to give to the aircraft people and to present before Congressional committees. There will be many problems where the Government wants something done and the only way to get it done will be to do it itself.

Dr. Briggs: This viewpoint is not peculiar to the aircraft industry. It goes throughout all industry in relation to any activities of the Government. They are anxious to have the Government conduct basic research but development they want left to themselves.

1. "(e) NACA should avoid establishment of facilities for research in those fields where industry is well equipped, i.e., radio, metallurgy, chemistry, fuel technology, etc."

Dr. Bush: We can avoid unnecessary duplication of facilities.

Admiral Pace: I have an idea that Dr. Whitney* will consider his organization competent to do all research necessary in the engine field.

The Chairman: They want all engine research stopped on the part of the Government.

Dr. Bush: Inasmuch as the Germans have just sprung a clever, new engine on us, which our industry never thought of, their attitude does not hit me very forcibly.

2. "(a) Whether or not NACA should allow the use of its facilities for the testing (and development) for industry of specific products. The present policy of the NACA concerning the use of its facilities for investigations for the industry of specific products is summarized as follows:

"The work desired must relate to aeronautics; must necessarily involve the use of NACA facilities, i.e., adequate facilities not available elsewhere; work is paid for by firm and results are its exclusive property against remainder of industry, but are available for use of the Government.

"The larger units of industry may be expected to be in opposition to the smaller plants having access to the use of NACA facilities.

"The question is, 'In the postwar period should the NACA adhere to this policy?' "

Admiral Pace: You will not want to let a strong financial concern come in and tie up all your facilities and so keep the weaker firms out. I got the impression that Mr. Gross† . . . did not realize that the NACA policy would permit him to come to the Committee and get necessary work done.

2. "(b) In the discussion at Cleveland with the representatives of the industry, there was considerable discussion about the sharing of public funds available for development. The industry inferred that it can use such funds to better advantage than Government laboratories in developing specific products and at the same time strengthen their own organizations."

Dr. Bush: Carried to its logical conclusion, the industry would let the NACA facilities lay idle.

The Chairman: The conclusion of one manufacturer was that the NACA should fold up. No other industry has such an organization as the NACA to help it along.

Dr. Bush: When it comes to the making of a specific product the industry can do it better than the Government.

---

*Unidentified; probably a jocular reference to Pratt and Whitney Aircraft Company
†Robert E. Gross, president, Lockheed Aircraft Corporation

General Echols: At Wright Field we agree to that but we never make a specific product unless we have to. The industry is afraid that we will, but we have no intention of doing so generally.

The Chairman: The industry feels that it is faced with the problem of survival.

3. "There is undoubtedly some misconception on the part of representatives of the industry as to aeronautical research versus aeronautical development. The Committee's laboratories in the postwar period would be concerned primarily with aeronautical research. The discussion noted above had to do primarily with engine research. It was recognized in discussion by the members of the Committee that there is a certain overlapping between the fields of research and development."

Dr. Bush: While the industry might claim that on fundamental research they could get more results per dollar, even though we granted that were the case from the general standpoint of the public interest, there remains the fact that when the NACA gets a result in fundamental research it becomes available to a large number; whereas when a single firm in industry gets it, it becomes available only after a lag. I cannot see any argument for keeping any Government research facility idle if their use will advance the art.

Dr. Warner: The fact that no other industry has had a Government laboratory goes along with the fact that no other industry has made such rapid technical progress as aeronautics.

General Echols: Industry is always looking over its shoulder at its competitors. If their research is one step ahead of their competitors they are satisfied. It has always been apparent they are not interested in the general progress of the art. The Government, in connection with the next war, has got to look many years ahead and constantly do things which will cost money in the research field and which many times may result in nothing gained.

4."(a) Realization that with NACA research results and test facilities available to all, the best engineering organization in the engine field may lose a competitive advantage won by their own enterprise."

Dr. Bush: The results we turn out in the engine field in the next twenty years are not going to enable any firm to build an engine unless he superimposes on that knowledge his own engineering. There is no limit to the engineering one can do in improving his product. I do not see why the company that maintains its engines on a high plane will lose anything to a competitor.

The Chairman: Several of the industry in visiting Cleveland commented that the NACA was concentrating on the Allison engine to improve its performance. That hurt their feelings.

General Echols: They just happened to find the NACA working largely on the Allison engine at that time. At some other time they might see a number of 3350* engines under study at the Cleveland Laboratory. When we have trouble with any type of engine we have to get busy and ask the NACA to push work on a single type.

The Chairman: It does not please Pratt and Whitney to see the Allison engine being benefitted by the Government.

4. "(c) Observation that NACA is leading jet propulsion and gas turbine developments in collaboration with firms previously outside the aeronautical engine field."

Dr. Bush: I do not think we need to duck that issue at all. The engine people did not do a thing on that subject or on any other unusual engine. If we brought new people into the engine field I think we have done a public service.

5. "(a) Extensive wind tunnel and engine testing facilities at Wright Field."

---

*The Cyclone 18, a Wright Aeronautical Corporation 18-cylinder 2200-hp engine used on the B-29 bomber "(b) Additional Navy facilities at Carderock, Philadelphia, and Patuxent."

The Chairman: It has been suggested to me that the NACA may be relieved of some of the routine work for the military services.

Admiral Pace: The character of the Navy facilities at Philadelphia has not changed. There is just more of it.

General Echols: The same is true of Wright Field.

5. "(c) Wind tunnel facilities at Curtiss-Wright, Pratt and Whitney, Boeing, California Institute of Technology, North American, and Lockheed."

Dr. Bush: I don't think the industry consulted the NACA about governmental policy before they built all their new wind tunnel facilities.

5. "(d) Power plant facilities at Pratt and Whitney, Wright Aeronautical, Allison, General Electric, Westinghouse, and Allis-Chalmers and proposed Packard engine test facilities at Toledo."

General Echols: The Packard Company's proposed new Toledo plant is a Reconstruction Finance Corporation proposition that was approved a long time ago. The engine industry is quite bitter about that. I don't know if we were starting again at this time we probably would not approve it. The industry is bitter about the Army putting the Packard Company into the aircraft engine business and keeping them in it.

GENERAL COMMENT

Chairman: What we are headed toward when there is no war is to keep our technological development going at first rate speed for the benefit of the Army and the Navy. Our competitor is going to be the British. They have had five missions over here recently to study recent additions to American research facilities and to learn everything they can. The latest is headed by Melville Jones.* They are going throughout the United States and they are frank in saying that what we have now is what they propose to build only larger and better. We have a 20-foot-altitude wind tunnel at Cleveland. They will have a 25-foot-altitude tunnel. Their program now calls for the construction of 12 wind tunnels which will constitute a great national research organization for the British empire.

Dr. Lewis: It was very interesting to me because for the first two years after the beginning of the war the British had to stop all research work and concentrate on development, and now they realize that the science of aeronautics has advanced rapidly. It is very interesting that they have been over here in several missions and have laid out a program for research and development facilities which practically duplicated what the NACA has developed in the United States. We really have an advantage at the present time. Sir Roy Fedden† recently gave a lecture.

(Dr. Lewis then read from Fedden's lecture remarks regarding the productive capacity of the British aircraft industry and how it had been increased several times and how they proposed to enlarge their research facilities.)

The Chairman: That has a bearing on the estimates the NACA may present to the Bureau of the Budget dealing with the question of how extensive should be our aeronautical research activities when there is no war. It involves a general policy concept.

General Echols: It appears that all of us are going to go to Congress with rather large postwar research budgets. It happens that the NACA is apparently one of the first that has been asked for its estimates.

---

*Sir Bennett Melville Jones, chairman, Aeronautical Research Council
†Minister of Aircraft Production

Dr. Lewis: I think there should be a joint effort on the part of the Army, Navy, NACA, and CAA‡ in presenting their research needs and in drawing up some policy that might satisfy the industry. I cannot understand why the industry feels bitter because they must realize there is, in fact, no competition to their activity provided by any of the NACA laboratories.

Dr. Bush: There are two questions: First, on what scale should the NACA try to operate; and second, on what policy? On the matter of policy it seems to me that the needs should be formulated. At first I thought there was no need for it, but after the discussion with the industry I think there is a great need for drawing the policy which can be placed before our group for adoption for our own guidance and then tell the industry where to stand. There is no necessity for doing that at once. I suggest that it would be a good idea to have a subcommittee work on that so that when we next meet we can have something before us in definite form.

The Chairman: Would it be your idea that General Echols, Admiral Pace, possibly Dr. Warner, and Dr. Lewis—could these four people as committee members draft a policy for the NACA?

Dr. Bush: I would suggest that you, Mr. Chairman, sit in with the group. I would make a motion that such a committee be asked to draw up a resolution to be presented at the next meeting; that the four gentlemen named study and prepare a statement on postwar policy for us.

The motion was duly seconded and carried and the Chairman announced that he would ask Dr. Lewis to serve as chairman. The other members to be General Echols, Admiral Pace, and Dr. Warner.

35. "Notes of discussions at meeting of National Advisory Committee for Aeronautics, April 26, 1945," undated.

[At the semiannual meeting of the NACA in April 1945, the issue of industry representation on the NACA and its technical committees arose. In contrast to the meeting summarized in document 34, industry representatives were present for this discussion. Still, the NACA yielded nothing on industry representation, one of the most troubling issues to face the Committee in the immediate post-war years. The tenor of the discussion shows how adamant the NACA was on this issue—and why. All those present, in addition to George Lewis and John Victory, were members of the NACA Main Committee; their full names and titles appear in App. B.]

Subject: Aircraft industry point of view regarding representation on NACA.

Mr. Burden: We had a discussion with members of the industry—Don Douglas, Gene Wilson and Bob Gross.* They expressed a desire for closer liaison with NACA activities than has been possible during wartime. They specifically made three suggestions: First, representation of the industry on the NACA working committees. The industry now is not really informed about what is going on. They suggested it might be possible to have their nominations made by the industry and let the NACA pick members from their nominees.

Mr. Littlewood: My thought is if the industry were to operate through its commercial agency, the Aeronautical Chamber of Commerce, appointments would not be directly representative because of geographical situations. A national organization

‡Civil Aeronautics Administration

*Donald W. Douglas, president, Douglas Aircraft Corporation; Eugene E. Wilson, president, United Aircraft Corporation; Robert E. Gross, president, Lockheed Aircraft Corporation which better represents the research side is the Institute of the Aeronautical Sciences, and I think that could be suggested to the Chamber as the agency to nominate people to work with the NACA.

Dr. Bush: That might work on an informal basis. It might be embarrassing if it became understood that the NACA could not function without the industry nominations.

Dr. Hunsaker: If we had suggestions from the industry we might select from such suggestions. I had a discussion with Don Douglas on the West Coast recently. Douglas said the committee members from his company were employees of his corporation chosen by the NACA without his knowledge or consent; that what went on in NACA subcommittees was known only to the members thereof. The industrial units do not get any results until a report is made—what went on was confidential discussion between the members of the committee. He said the thing to do was to put on the committees accredited representatives of the industry who would be their watchdog on the committee and would report to all of the industry democratically what was going on and what was planned. I thought that was outrageous—that our committees would shrivel. We have built up over the years quite free and frank discussions between the people who are normally competent & exchange a good deal of advice and counsel and give us on the Main Committee advice as to the direction on which we should go. The appointment of industry representatives sounds very innocent, but if they are appointed for the purpose of being representatives, it would upset our applecart.

Dr. Bush: I feel strongly that we cannot get into the position where industry can tell us who we may have on the committees. It would be fatal.

Mr. Burden: Douglas proposed that we should have the veto power.

Dr. Hunsaker: Did he propose that the people would report back to their companies what was going on?

Dr. Warner: They want members responsible to the industry as a whole.

On request of the Chairman Mr. Victory gave an analysis of the subcommittee membership, stating that there are six major and eighteen subordinate technical committees, with a gross membership of 244, of whom approximately one-half are from industry, including twenty airplane-manufacturing firms, six engine manufacturers, and twenty-one other allied or supporting industries.

Dr. Hunsaker: Should we form an industrial consulting committee?

Dr. T. P. Wright: I think we ought to adopt this first point.

Dr. Bush: On some things it would be very helpful to have a subcommittee member from one industry visit and report to other industries, but it might be fatal.

Dr. T. P. Wright: We are asking an aerodynamics committee member from industry to visit other firms and bring in information.

Mr. Littlewood: The industry wants early access to the problems under discussion. Maybe if the subcommittees were to put out interim reports more frequently that might answer the need.

Dr. Bush: If we are having close contact with some manufacturer, it would be a big advantage to him to have up-to-the-minute information which he might incorporate in his product.

Dr. Hunsaker: You have Colonel Carl Greene* at Langley Field, and the industry's designers go down there, live in his office, and sit in with our laboratory heads.

Mr. Burden: I think there must be some personal contact. The industry is unhappy about it. We will save ourselves a lot of trouble in the long run. I do not see why it should run us into considerable difficulties.

---

*Col. Carl F. Greene, U.S. Army Air Forces, liaison officer, Langley Laboratory.

Dr. T. P. Wright: I suggest that the industry nominate three East Coast and three West Coast representatives for each committee and we select one and give him instructions.

Dr. Hunsaker: Would they be members or observers? A mere observer would spoil discussion.

Dr. Bush: I suggest the subcommittees might have meetings with the industries as guests. I think our subcommittees must have members who take an Oath of Office and represent only the United States Government in any units of the industry.

Dr. Hunsaker: Suppose we asked the Aeronautical Chamber of Commerce "Will you suggest three names for our consideration?" on a given committee. The committee controls its appointments. If a member does not behave, we can bounce him.

Dr. Lewis: Would that prevent the NACA from appointing others from industry?

Dr. Hunsaker: They would be appointed from the Institute of the Aeronautical Sciences.

Mr. Burden suggested that a special committee be appointed by the Chairman to consider the matter and report at the next meeting. The Chairman asked if there was any objection. Hearing none, he announced he would appoint a special committee composed of Dr. Lewis, Dr. T. P. Wright, and Mr. Littlewood.

Mr. Burden: Their second suggestion was the appointment of an advisory committee of the heads of industry who could have an opportunity to sit down with the NACA and talk over general problems like we did last year at the Cleveland and Ames Laboratories. In doing that we could build up good personal relations.

Dr. Hunsaker: Then they would come prepared to discuss our programs. We practically invited that kind of relation last year by asking them to visit the Cleveland and Ames Laboratories and to discuss problems with them. I agree that where we are badly off in our public relations is with the financial heads of the large manufacturers. You, Burden, might head a panel to recommend who in the industry might be honored by our invitation. I suppose our transport industry should also have representation.

Mr. Littlewood: I suggest that the Vice Presidents in charge of Engineering should be the representatives.

Dr. Hunsaker: Will you, Burden, be a panel of one to make a proposal?

Mr. Burden: Yes, but I would like to work with you and Lewis on that.

Dr. Hunsaker: It is agreed that at the next meeting we will consider two methods of adminstration and organization that bear on our relations with the industry.

Mr. Burden: The third matter in which industry is concerned is the appointment of a member of the industry on the Main Committee as an industry representative. They suggested that the president of the Aeronautical Chamber of Commerce be a statutory member. We stated we did not agree with that.

Dr. Hunsaker: The president of the Aeronautical Chamber of Commerce would be an ex officio statutory member? Amend the law? Is that it?

Mr. Burden: Yes. That is it.

Dr. Bush: I do not think Congress would like that.

Mr. Victory: I suggest the importance of the members keeping in mind that the NACA is a governmental organization created by law as such to represent the government's interests, and that there is great danger of the Committee's losing its standing and influence if it becomes known that it is a spokesman for industry. Some years ago the Aeronautical Chamber of Commerce appointed a technical committee to prepare a program of problems which the Chamber recommended that the NACA investigate.

The NACA considered the matter, agreed that the problems were good and worthy of investigation, and submitted a supplemental estimate of appropriations to finance the work. That was the only time in the entire history of the NACA that one of its recommendations was flatly rejected and it drew a rebuff from the Bureau of the Budget because, as the Bureau expressed it, the NACA was not established to be a special pleader for industry.

Mr. Burden: I don't think we ought to do it.

36. "National Aeronautical Research Policy," approved 21 March 1946.

[The result of almost two years' discussion and negotiation (documents 33–35), this policy statement sets forth the division of responsibilities and functions within the American aeronautical community. Though the NACA assumed no political role beyond coordination of parallel research activities, this document is nevertheless as intensely political as the parallel policy statement published by the Committee after World War I (document 18). For example, the Committee clearly was arguing for sustained appropriations, even though the war was over, and the division of functions among major American aeronautical institutions implicitly excluded private aviation and small inventors, operators, and manufacturers from NACA consideration. Furthermore, the NACA conceded more here to the aviation industry than ever before.]

1. Experience since the establishment of the National Advisory Committee for Aeronautics by the Congress in 1915 has shown that the value of the airplane for national defense and for commerce has directly followed the evolution of an advancing technology based on research. Research made rapid strides as more facilities were provided for the NACA. The Army and Navy explored military applications of NACA fundamental research results with the aid of their increased facilities for testing and evaluation. The aircraft industry, by the exercise of great initiative and technical competence, developed superior airplanes of both military and civil types to meet ever-increasing performance requirements.

2. The effects of accelerated enemy research and development in preparation for war helped to create an opportunity for aggression which was promptly exploited. This lesson is the most expensive we ever had to learn. We must make certain that we do not forget it.

3. During the war, the NACA has greatly expanded its research facilities at Langley Field, Moffett Field, and Cleveland, while the Army and Navy have correspondingly increased their facilities for testing and evaluation. Furthermore, the aircraft industry has been able to provide extensive development facilities of its own. As a result, American airplanes are today superior in most respects.

4. This lead may or may not be continued in the post-war period, depending on whether the present facilities in the country are used to full effect to advance the science and the technology of aeronautics. Results already obtained make it apparent that there are further opportunities for substantial improvement in the performance of aircraft and equipment which can be realized only by vigorous research and development programs.

5. It is possible to assume that the United Nations will, by repressive measures, eliminate hostile competition in the air. Nevertheless, it is essential so to continue research as to assure American leadership in military aviation development. It is moreover certain that between the United Nations vigorous commercial competition will take place. In fact, we already are informed of extremely ambitious plans to surpass present American research equipment, obviously in a desire to excel in the air.

6. The Committee believes it to be in the public interest to foster a greatly increased civil use of the airplane, for domestic and international airlines and for

private operation. A vigorous civil aviation can affect favorably our domestic and international relations, both economic and cultural. At the same time it will contribute to national security by the support of a reserve of airplanes; operating, development, and manufacturing facilities; and civilians trained in the skills which are critical in time of war.

7. The rate of growth of civil aviation will depend on the rate at which improvements in safety, performance, reliability, utility, and economy can be realized. However, to realize such improvements, research must solve some difficult problems associated with operations over extended ranges of distance and altitude, aggravated by the extension of airlines over areas of unusual weather and terrain.

8. Some of the results of war research can be applied by the aircraft industry directly to new designs of civil airplanes. In many cases, however, practical applications have yet to be discovered and require further research directed toward the solution of specific problems. Neither the airlines nor the manufacturers can be expected to solve these problems quickly without the assistance of intensive research by the NACA and development by the industry.

9. The NACA should, therefore, endeavor to direct an increasing proportion of its research effort to the technical problems of civil aviation with a view to their practical solution.

10. Experience clearly indicates that in time of peace the application of research results to military and naval objectives is extremely important. Possible military applications must be explored by continuous experiment and testing by professional soldiers and sailors as a life work, and the developments of industry must be evaluated by the military users. Such exploration and evaluation require the use of the facilities now available to the Army and Navy.

11. The public interest requires that effective use be made of existing facilities for research, development, and evaluation, and that they be kept modernized and new ones added as the progress of the art requires. Outmoded facilities should not be used simply because they exist. The results of research conducted at public expense should be made available to manufacturers and operators in such a manner as to stimulate the growth of healthy competition in the supply of goods and services.

12. It is recommended that the Army Air Forces, the Bureau of Aeronautics of the Navy Department, the Civil Aeronautics Board and the Civil Aeronautics Administration of the Department of Commerce, and the NACA follow, in so far as may be practicable, the following general policy considerations in the post-war utilization of research, experimental and testing facilities of the Government and their relation to the development facilities of the aircraft industry.

A. Fundamental research in the aeronautical sciences is the principal objective of the NACA. Such research is directed toward the solution of the problems of flight and results are promptly published. In exceptional cases research results of potential military importance may be withheld from publication.

B. Research of the NACA is not considered completed until results are tested by sufficient practical application. However, NACA research will not include the development of specific aircraft or equipment.

C. Research programs of the NACA are formulated in close collaboration with technical personnel from the Government agencies concerned and from industry through membership on appropriate subcommittees. Members of all technical subcommittees of NACA are appointed as individuals especially qualified in their particular fields.

D. The research facilities of the NACA may be used upon request by a Government agency in evaluation of specific aircraft and equipment, whenever facilities available to that agency are inadequate.

E. The research facilities of the NACA Laboratory may be used to assist private individuals and corporations whenever other facilities are not available and NACA facilities are available provided that the investigation is considered by the NACA to be worth making. If the investigation is considered by the NACA to be in the public interest and the private individual or corporation agrees, the work may be undertaken at public expense and the results published. If the investigation is primarily of private interest, the cost should be met by those requesting assistance and the results reported only to them.

F. Application of research results in the design and development of improved aircraft and equipment, both civil and military, is the function of the industry, assisted as may be necessary by contracts for experimental articles, placed in a manner to stimulate competition for quality. It is recognized that the encouragement of competitive engineering organizations is essential.

G. The evaluation of military aircraft and equipment developed by the industry, and the exploration of possible military applications of research results are considered to be the function of the Army and Navy.

H. Expedition of the practical use in civil aeronautics of newly developed aircraft and equipment, in so far as Government assistance may be necessary, is considered to be the function of the Civil Aeronautics Administration.

I. The NACA normally will use its own research facilities, but will contract with university and other private research organizations for work in special fields where outside facilities and competence are to be found. Likewise, the facilities and competence of the National Bureau of Standards, Forest Products Laboratory, and other Government research centers will be used by the NACA whenever practicable.

J. Unnecessary duplication of facilities and effort will be avoided by adherence to the principles stated above, but for important problems whose practical solution appears to be especially difficult, parallel attack by several independent research teams is necessary. In such case, the NACA, the aircraft industry, Army, Navy, and Civil Aeronautics Administration, Department of Commerce and individual scientists and inventors may work on various aspects of the same basic problem. Such parallel attack must be coordinated, and it is the policy of the NACA to achieve such coordination through the medium of subcommittees of experts representing all concerned.

37. National Advisory Committee for Aeronautics, "A Proposal for the Construction of a National Supersonic Research Center," April 1946.

[The advent of jet propulsion during World War II raised the prospect of supersonic flight, even though the "sound barrier" was not broken until 1947. Wind-tunnel research at supersonic speeds required enormous amounts of power, demands that soon would have overtaxed local utilities at existing NACA laboratories if the Committee had built all the tunnels it envisioned in the immediate postwar period. Prompted by news that the Army Air Forces were planning their own supersonic research facility, the NACA rushed into print with this proposal for a national supersonic research center. This was the Committee's opening move in a three-year struggle that culminated in the National Unitary Wind Tunnel Plan Act of 1949. In the course of the struggle, this plan was at first expanded to even more grandiose proportions, and was then reduced drastically at the hands of the Bureau of the Budget and Congress. The NACA never got its national supersonic research center; events were to prove that it never needed one.]

SUMMARY

Recent trends in the advancement of the aeronautical sciences have emphasized the urgent need for accelerated research on aerodynamic and propulsive problems associated with aircraft traveling at speeds greater than the speed of sound.

Supersonic research facilities of the size and speed required for conducting fundamental research on these problems are not available, and the utility requirements of such facilities cannot economically be met at any one of the existing laboratory sites of the National Advisory Committee for Aeronautics.

It is proposed that steps be taken at an early date to obtain authorization for the National Advisory Committee for Aeronautics to begin construction of a National Supersonic Research Center on a site to be selected by the Committee.

Preliminary estimates of the cost of the Supersonic Center total $162,000,000 for the first five-year period. The initial request for authorization would include appropriation requests totaling $5,500,000, of which amount $1,500,000 would be required for preliminary design studies and $4,000,000 for initiating construction during the first year.

INTRODUCTION

Advancement of the natural sciences is the key to national security and prosperity. In a military sense, national security demands superiority in the air. Military leaders agree that existing air weapons will be obsolete when the barriers to supersonic flight have been overcome. Experience has shown that a time lag of from 5 to 10 years occurs between the discovery of a scientific principle and its practical application. Fundamental research must therefore substantially lead development. In the interests of defense and preservation, our nation must be the first to master the science of supersonic flight. To this end a comprehensive integrated program of supersonic research must be initiated and accelerated, and adequate facilities for conducting the research must be provided.

The National Advisory Committee for Aeronautics was established by Act of Congress in 1915 "to supervise and direct the scientific study of the problems of flight with a view to their practical solution." In fulfilling this responsibility the Committee has conducted fundamental research at its three laboratories located at Langley Field, Moffett Field, and Cleveland. These laboratories are largely devoted to research at subsonic speeds and were instrumental in providing the basic research information that led to the successful military airplanes of the past war. Research of limited scope has also been conducted at supersonic speeds. Existing facilities are in no way adequate to provide a sound scientific foundation for supersonic flight. Additional equipment is required if leadership in this field is to be achieved.

The National Advisory Committee for Aeronautics has been intensively studying supersonic research problems and the additional research facilities necessary for their solution. A summary of this study, including an outline of suggested new research equipment and a method of immediate approach to the problem, is given in this report.

SUPERSONIC RESEARCH PROBLEMS AND TECHNIQUES

Research at supersonic speeds is in an embryonic stage comparable to the state of development of subsonic research in the early days of flying. A brief statement of the scope of the research to be accomplished and a description of research techniques will indicate the present state of the science and provide justification of the methods proposed to accelerate research activity.

Research Problems. Research in all fields of aeronautics is directed toward the ultimate solution of the practical problems of flight. In this respect the general research objectives in the subsonic and supersonic regimes are similar. The solutions of research problems, however, are not similar. In subsonic flight, pressure disturbances are propagated ahead of a body and streamlines are deflected so as to pass smoothly over it. In contrast, at supersonic speeds disturbances are not propagated upstream, and the streamlines are abruptly deflected at the nose of the body by flow discontinuities called shock waves. The essentially different flow mechanism of the supersonic range requires new solutions for the major aerodynamic and propulsion problems.

Many undeveloped concepts exist in the new field that require study of:

1. The origin, propagation, structure and interaction of shock and expansion waves.
2. The development of laminar and turbulent boundary layers and their behavior in the presence of self-induced shock and expansion waves.
3. Upstream propagation of disturbances through wakes and boundary layers and the nature of separation effects.
4. The nature of development of pressures on wing surfaces as affected by airfoil contours, wing plan forms, and other geometric variables.
5. Pressure distributions and origin of drag for bodies of revolution as affected by the geometry of the body.
6. The fundamentals of interaction of wing-body combinations.
7. Aerodynamic variables in the transition range from subsonic to supersonic flow.
8. Fields of flow ahead of and behind lifting surfaces and bodies.
9. Fundamental propulsion arrangements for aircraft.
10. Aero-thermodynamic relationships for internal flow systems at supersonic speeds.
11. Non-stationary flow phenomena.
12. Surface temperatures at supersonic speeds and basic methods for heat dissipation.

The foregoing list includes but a minor fraction of the many fundamental research problems that must be investigated. In addition there are broad fields of systematic research on each of the various components of supersonic aircraft that will provide a firm basis for the practical application of supersonic principles and lead to the formulation of new concepts.

The scope and variety of the enumerated research problems provides only a partial indication of the magnitude of the research that must be accomplished; each of the problems must be investigated over a wide range of airflow Mach numbers and Reynolds numbers. Flow Mach numbers in the range from 1 to 10, that is in the speed range from one to ten times the speed of sound, must be thoroughly studied in the next few years to provide the basis for design of piloted and pilotless aircraft. Flight at speeds greater than ten times the speed of sound must be tentatively explored for bodies that are to be flown in the upper limits of the atmosphere.

The effect of Reynolds number, or scale effect, must be investigated for a range of various size aerodynamic bodies, from small compressor blades to wings of large man carrying aircraft. Preliminary investigations on bodies of revolution have already shown that the scale of the body has an important effect on its aerodynamic characteristics. Whether the flow in the boundary layer is laminar or turbulent depends upon the scale of the tests and the effect of interactions of shocks with these two types of boundary layers has tentatively been shown to be different.

The necessity for adequately exploring the broad range of flow Mach numbers and Reynolds numbers with models of sufficient size so that aircraft and engine geometry can be accurately reproduced introduces the real urgency for more extensive research facilities.

Research Techniques. Experimental techniques utilized in subsonic and supersonic research are similar in character, thus parallel types of research facilities are employed in the two branches of the science. Principal techniques include:

1. Wind-tunnel investigations.
2. Flight studies with piloted aircraft and with pilotless aircraft and bodies.
3. Drop tests of bodies from high altitude.
4. Electric and hydraulic analogies.

These research techniques are all useful and continuous effort is exerted to extend their usefulness by development of instrumentation.

The wind tunnel, however, is by far the most important aeronautical research tool. The major portion of all aeronautical research data upon which the science of flight is based was obtained in wind tunnels. The advantage of the wind-tunnel technique results from the expediency with which extensive measurements can be made under widely varying test conditions. Modern subsonic wind-tunnel technique provides instrumentation for recording more than a thousand simultaneous research measurements.

Acceleration and intensification of supersonic research activity requires wind tunnels in sufficient number and of adequate size and speed so that the useful wind-tunnel technique can be fully exploited.

Wind tunnels for subsonic and supersonic research, although generally similar in character, possess different degrees of flexibility with reference to possibilities of varying operating speeds and size of models that may be investigated. Flexibility in the use of supersonic wind tunnels is determined by the following requirements:

1. Models must be small enough in cross section so that a normal shock resulting in conversion of the flow from supersonic to subsonic will not occur in the test section, and
2. The models must be sufficiently short so that supersonic waves generated at the nose of the models are not reflected back from the tunnel walls on the rear of the models.

Flexibility in the design of supersonic wind tunnels is limited by:

1. Wind-tunnel compressor characteristics.
2. The design requirements of the mechanism for changing the wind-tunnel Mach number.
3. Model support design requirements.

These considerations define the range of Mach numbers and Reynolds numbers that may be investigated in a single wind tunnel, and provide the basis for establishing the minimum number and types of supersonic wind tunnels required for adequate coverage of the broad fields of research.

Facilities for applying other research techniques are also required to supplement the wind-tunnel research and provide the evaluation of final results.

SUPERSONIC WIND TUNNELS EXISTING AND UNDER CONSTRUCTION

Supersonic wind tunnels in operation and under construction by the National Advisory Committee for Aeronautics are as follows:

Laboratory	Size of test section	Maximum Mach number	Use
EXISTING FACILITIES			
Langley	4 by 18 inches	1.4	Aerodynamic
Langley	9 inches	2.4	Aerodynamic

Laboratory	Size of test section	Maximum Mach number	Use
Ames	8 by 8 inches	2.3	Aerodynamic
Ames	1 by 3 feet	2.5	Aerodynamic
Cleveland	18 by 18 inches	2.2	Aerodynamic & Propulsion
Cleveland	20-inch-diameter	2.0	Aerodynamic & Propulsion
FACILITIES UNDER CONSTRUCTION			
Ames	1 by 3 feet	3.4	Aerodynamic
Cleveland	2 by 2 feet	4.5	Aerodynamic & Propulsion
Langley	4 by 4 feet	2.2	Aerodynamic
Ames	6 by 6 feet	1.8	Aerodynamic
Cleveland	8 by 6 feet	1.8	Aerodynamic & Propulsion

The 4- by 18-inch tunnel at Langley Field is of the induction nonreturn type and can be used only for short periods of time. It is operated by discharging compressed air from a large tank through ejector nozzles, thereby inducing high-velocity air flow in the tunnel test section. The 9-inch tunnel is of the direct-action return type, and is driven by a 1,000-horsepower axial flow compressor. These tunnels are used for preliminary investigations of the aerodynamic characteristics of very small models in the supersonic speed range.

The 8- by 8-inch tunnel at Ames is of the nonreturn type and is powered by three compressors totaling 4,500 horsepower. This tunnel serves as a pilot tunnel for designing wind-tunnel nozzles and diffusers. The existing 1- by 3-foot tunnel is of the single return type and is driven by compressors with a total installed horsepower of 10,000. It is used for aerodynamic investigations of small airfoils and bodies at supersonic speeds and for fundamental studies of supersonic-flow phenomena. The pressure in the tunnel can be varied to permit research to be conducted over a range of Reynolds numbers.

The supersonic tunnels at Cleveland are operated by the equipment already provided for evacuating the Altitude Wind Tunnel. During periods when the Altitude Wind Tunnel is not in operation, its large exhauster pumps are used to draw air through the supersonic tunnels. The primary purpose of these tunnels is to investigate the fundamentals of small-scale propulsive systems suitable for powering supersonic aircraft.

The Ames 1- by 3-foot and the Cleveland 2- by 2-foot supersonic wind tunnels now under construction will extend the speed range available for small-scale aerodynamic and propulsion research. The other three wind tunnels under construction represent the Committee's most advanced effort toward the construction of equipment for supersonic research. These tunnels are a first approach to the problem of obtaining facilities that will provide results on models of larger sizes, higher Reynolds numbers, and higher Mach numbers. The Langley 4- by 4-foot wind tunnel is a closed-return tunnel and is equipped with a 6000-horsepower drive motor. It operates at reduced pressure simulating altitude conditions.

The Ames 6- by 6-foot wind tunnel is generally similar in arrangement to the Langley 4- by 4-foot tunnel, but operates at higher pressures with resultant higher Reynolds numbers and a greater power absorption. Motors delivering 50,000 horsepower drive the larger Ames tunnel. Both wind tunnels are adapted to aerodynamic research on two-dimensional and three-dimensional models considerably larger in size than can be tested in existing supersonic wind tunnels.

The 8- by 6-foot supersonic wind tunnel now under construction at the Cleveland laboratory is a nonreturn tunnel designed specifically for research on supersonic propulsion systems. Models of engines will be operated under full power at simulated conditions of flight and at speeds exceeding 1300 miles per hour.

In summary it may be stated that the use of the available research facilities and those under construction will result in the attainment of further knowledge of the mechanism of supersonic air flow, will lead to a better understanding of the requirements for improved airfoils, body shapes and propulsion systems, and will result in the development of improved instrumentation and testing techniques. The results of research in these wind tunnels will provide a step in the evolutionary process leading toward a complete understanding of the characteristics of full-scale supersonic aircraft. These facilities, however, are subject to the following limitations:

1. Many important research problems associated with stability, control, flight-handling characteristics, and propulsion cannot be investigated at Reynolds numbers approaching those encountered in flight nor can certain special research problems requiring models of larger size be adequately investigated.

2. No equipment exists or is under construction for research at Mach numbers above 4.5, whereas a comprehensive and integrated program of research should include facilities for investigation over a range of Mach numbers up to at least 30.

PROPOSED SUPERSONIC RESEARCH FACILITIES

In order to meet the existing and urgent need for more advanced supersonic research facilities, it is proposed that a National Supersonic Research Center be constructed, the first phase of the construction to be as follows:

1. Supersonic wind tunnels of comparatively large scale to cover the range of Mach numbers of 0.8 to 10 for both aerodynamic research and research on propulsion systems.

2. Supplementary facilities and services for exploring at smaller scale the fundamentals of flows at Mach numbers as high as 20 to 30.

3. Facilities for full-scale research on propulsive systems that use normal fuels or hazardous fuels.

Equipment. Preliminary studies of the proposed equipment indicate that it is not feasible at the present time to attempt the design and construction of wind tunnels for full-scale research on complete airplanes at supersonic speeds. In wind tunnels that can be built at this time, however, it will be possible to conduct research at Reynolds numbers approaching full-scale values and to investigate many aerodynamic and propulsion elements at full-scale.

The following supersonic wind tunnels are recommended for construction:

Identification	Height of Test Section	Mach Number	Purpose
A	20 ft. to 30 ft.	0.8 to 1.6	Aerodynamic
B	10 ft. to 15 ft.	1.5 to 2.6	Aerodynamic
	6 ft. to 10 ft.	2.0 to 3.0	Aerodynamic
	6 ft. to 10 ft.	3.0 to 4.8	Aerodynamic
C	6 ft. to 10 ft.	4.8 to 7.0	Aerodynamic
	6 ft. to 10 ft.	7.0 to 10	Aerodynamic
D	10 ft. to 15 ft.	1.5 to 2.6	Propulsion

A—Aerodynamic research, primarily on configurations, stability, and control, and factors affecting maneuverability of piloted supersonic aircraft.
B—Research on aerodynamic elements and configurations of supersonic piloted and pilotless aircraft, and on the aerodynamics of propulsion.
C—Aerodynamic research for new concepts, for basic design data and for specific information, on pilotless aircraft particularly of the rocket type.
D—Propulsion research permitting duplication of internal and external conditions of power plants and their installations under the range of altitude and temperature conditions of interest.

. . . Each of these four wind tunnels will require drive motors of approximately 450,000-horsepower capacity.

These major facilities will be supplemented with less powerful but important aerodynamic research facilities and services for exploring the physical nature of flows at Mach numbers as high as 20 to 30.

Essential investigations on propulsion systems for supersonic flight will be carried forward in special facilities that will provide sufficient dry refrigerated air to operate jet engines of more than 40,000 pounds thrust. Since altitude exhaust facilities will also be installed, the internal flow systems of large engines will be subjected to conditions duplicating actual flight at supersonic speeds.

One of the extremely promising fields of research on engines for supersonic flight is the study of fuels of high energy content per unit of volume. It is characteristic of such fuels that the energy is released at a rate which greatly exceeds the heat output from the combustion of normal hydrocarbon fuels. Until such time as the new types of fuels can be fully investigated and brought under proper control, an element of danger is involved in their handling. For this reason a Hazardous Fuels Laboratory will be provided at some distance from other facilities at the laboratory site, and it will have suitable devices to protect in every possible way the safety of the operating personnel.

Instrument-research facilities are included in the program so as to ensure proper facilities for investigations of research instruments and techniques. The true value of supersonic research equipment can be realized only if the scientist has at his disposal an accurate and reliable means for measuring the many complex physical phenomena involved in the investigation. Because of the many new problems encountered in advanced research on supersonics, numerous new instruments must be devised and made available to the aerodynamicist.

In addition the program contemplates the construction of the necessary service and administrative facilities. A tentative plan for the arrangement of the proposed facilities is presented on the following page.

Personnel. In research, the quality of the workers is all important. Key men for the proposed National Supersonic Research Center are available in the present NACA staff, but an intensified recruiting and training program will be required to ensure that a sufficient number of highly qualified specialists will be available when the new facilities are completed. It is proposed to accomplish this through the existing training program within the NACA and by means of arrangements with universities for advanced studies in special fields of applied science.

SITE REQUIREMENTS AND SITE SELECTION

The basic requirements of a site suitable for the construction and operation of the research equipment herein proposed may be summarized as follows:

1. Continuous availability of low-cost electric power in accordance with the following schedule:

Within 3 years: 300,000 kilowatts, 600,000,000 kilowatt-hours per year
Within 5 years: 500,000 kilowatts, 1,000,000,000 kilowatt-hours per year

Ultimate: The power potential of the area within transmission distance of the laboratory site shall be capable of development so as ultimately to provide power in quantities several times the figures indicated for the five-year period.

2. Cooling water, sufficiently clean, pure, and cool for use in heat exchangers, in adequate quantity up to 300,000 gallons per minute.

3. Adequate land for the construction of the research facilities in an area where the topography of the adjacent terrain is suitable for flight research with piloted supersonic aircraft.

4. Climatic conditions which will provide clean, dry air and good flying weather.

5. Adequate transportation and communication facilities, access to industrial centers.

6. An area near the site suitable for the development of a community, or the expansion of an existing community, to provide satisfactory living conditions for personnel.

No one of the Committee's three existing laboratories can meet the site requirements. Preliminary surveys indicate that a site meeting all requirements may be found in at least one of the following areas:

1. The Columbia River area in the vicinity of Grand Coulee Dam, Washington.

2. The Colorado River area in the vicinity of Boulder Dam, Nevada.

3. The Central California area served by the Pacific Gas and Electric Company.

The final selection of a site must be based upon a thorough study of possible sites in all three areas. The advantages and disadvantages of each possible site must be analyzed in detail on the basis of engineering, economic, and environmental considerations.

PLAN OF CONSTRUCTION

The large size of the utility installations and research facilities proposed for the National Supersonic Research Center presents a number of unprecedented problems in engineering design. It is estimated that a period of approximately one year will be required for preliminary engineering design studies to provide adequate information for the preparation of detailed specifications. It is proposed to accomplish the preliminary studies by an integrated program involving pilot investigations, detailed analysis, and study by Committee research experts, supplemented by the services of experienced industrial engineering firms and consultants employed under contract.

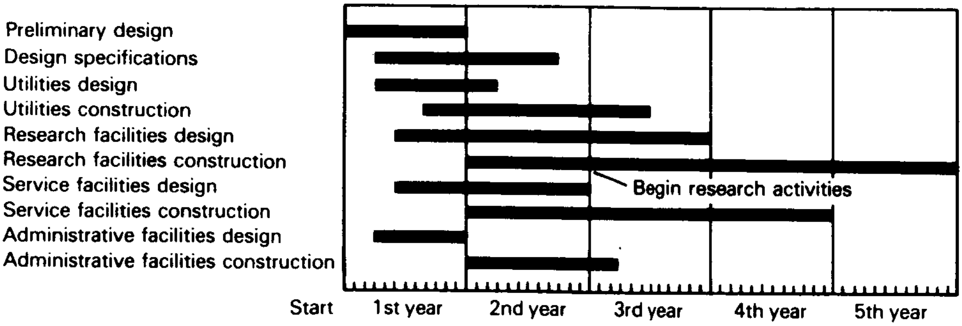
It is proposed that funds be requested in an amount adequate to permit the assignment by the Committee of an initial staff of 30 employees to this project to be increased gradually during the period of one year to approximately 210. This staff will be engaged (1) on research investigations using pilot equipment for the solution of basic design problems, (2) on the preparation of design requirements and design specifications, (3) on the design of certain equipment and instrumentation which requires a specialized knowledge of research, and (4) in performing the essential planning, administrative, and coordination functions involved in a construction project of this character.

Concurrent with these activities, arrangements will be made to enter into contracts with competent industrial engineering firms and consultants to furnish detailed design information including plans and specifications on many phases of the project. The use of outside services in this manner, particularly on such items as the optimum design and layout of utility installations, road construction, land improvements, water-purification and -cooling systems, and drive motor and compressor construction, is considered essential to ensure the construction of a workable and economical laboratory.

The [following] chart . . . indicates the estimated schedule for the design and construction of the facilities proposed for the Supersonic Center. It is estimated that design information on some phases of the utility system will be available in time to begin construction during the first year.

The amounts recommended under (a) and (b) above represent the best estimates that can be made at this time of the sums that could efficiently be obligated during the fiscal year 1947. As preliminary design studies are completed, the Committee will be in a position to prepare and submit accurate estimates of the appropriations that will be required annually to complete the project.

Tentative schedule for design and construction, National Supersonic Research Center, during first 5-year period.



38. Langley Memorial Aeronautical Laboratory, "Appraisal of German Research during the War Relative to that of the NACA," [Oct. 1946].

[In response to widespread suspicion that the NACA had been bested by the Germans in aeronautical research just before and during World War II, the Langley laboratory staff prepared this comparison, based on the NACA's record and on investigations made in 1945 and 1946 into German achievements. Although this analysis does provide a fair summary of aeronautical progress in World War II its evaluation of the relative achievements of the Germans and the NACA must be taken with caution. The tone is so defensive and the treatment so one-sided (for example, the discussion of jet propulsion) that, in keeping with Jerome Hunsaker's advice, the analysis was never published.]

AIRFOILS AND HIGH-LIFT DEVICES

In general, the major portion of all the airfoil research carried out by the Germans was carried out either on NACA airfoil sections or on modified NACA airfoil sections. Furthermore, the methods used for modifying the airfoil sections were those previously developed by the NACA. The Germans have not developed methods of relating airfoil shape and angle of attack with pressure distribution to the degree of refinement that has been achieved by the NACA, nor have they correlated the aerodynamic characteristics of airfoil sections with their pressure distributions as closely as has been done by the NACA.

The problem of reducing skin-friction drag of wings by maintaining extensive laminar flow in the boundary layer was the subject of much research in many countries before and during the war. The Germans expended considerable effort on theoretical investigations of the stability of laminar boundary layers. Schlicting* made some of the most significant contributions to this subject. The final results of Schlichting's calculations indicated that laminar boundary layers in a region of favorable pressure gradient were stable to much higher Reynolds numbers than those in unfavorable gradients, but that, in any case, if transition occurred when the boundary layer first became unstable, the extent of laminar flow obtainable at flight values of the Reynolds number was relatively unimportant. This result is to be contrasted with the results of NACA investigations which showed extensive laminar flow on smooth low-drag airfoils in a low-turbulence airstream up to Reynolds numbers of more than 40 million.

As an extension of Schlichting's work, a number of theoretical investigations were undertaken in Germany to determine whether or not the lower critical boundary-layer Reynolds number could be increased by means of boundary-layer suction. These theoretical investigations indicated that the application of continuous suction, such as might be obtained through a porous surface, might permit laminar flow to be obtained at nearly any flight value of the Reynolds number. No experimental work was done, however, either to develop suitable porous surfaces or to check the theory. NACA investigations conducted prior to our entry into the war indicated that the use of multiple suction slots did not reduce the difficulties associated with maintaining sufficiently smooth surfaces for laminar flow at high Reynolds numbers.

Perhaps because the results of Schlichting's calculations indicated the improbability of obtaining significant amounts of laminar flow at useful Reynolds numbers, the Germans appear to have done comparatively little research work on low-drag airfoil sections such as those systematically investigated by the NACA. Several early type NACA low-drag airfoil sections, descriptions of which fell into German hands after the fall of France, as well as several German-designed laminar-flow sections which were similar to the early NACA types, were tested. In nearly all cases, however, the German airfoils had unnecessarily small leading-edge radii and poor trailing-edge shapes with the result that the observed maximum lift coefficients were low. Furthermore, none of the wind tunnels in which tests were carried out had turbulence levels sufficiently low to achieve large extents of laminar flow in the practical flight range of Reynolds numbers.

In an effort to increase the maximum lift coefficients obtainable with plain airfoil sections, a considerable amount of German research was concerned with the development of high-lift devices. Although some rather unusual configurations were tried, most of the trailing-edge high-lift devices tested, such as the plain, split, slotted, and double slotted flaps, were similar to those investigated by the NACA. . . .

Further increases in the maximum lift coefficient were obtained by means of boundary-layer control. Investigations of both blowing and sucking slots were made in Germany and, in some cases, more than one slot was used. These investigations generally paralleled those of the NACA, although the configurations were naturally not identical.

At about the start of the war the Germans recognized the applicability of swept wings for flight at high Mach numbers, and most of their subsequent three-dimensional wing research during the war concerned the properties of such wings. They noted the characteristic boundary-layer cross flows and the poor stalling, and spent considerable effort in testing various fixes, such as boundary-layer control, leading-edge slats and flaps, fences, and washout. NACA wing research until 1945 was concerned mainly with

---

*Hermann Theodore Schlicting, director of the Institute of Fluid Mechanics, Technical Institute of Braunschweig.

unswept designs for particular purposes and with correlation of section and wing characteristics, with special emphasis on wings having high-speed sections; and swept wings had been studied mainly with regard to their use on tailless airplanes. When, in 1945, the development of suitable power plants made transonic flight appear possible, the NACA independently recognized the applicability of swept wings for high-speed flight. Immediate attention was directed to research on such wings with the result that the German data, when they became available, were supplemented by NACA data at transonic speed where no German data were obtained.

With regard to the calculation of span-load distributions on swept wings, methods that satisfy the downwash condition at the three-quarter chord line were developed both by the NACA and in Germany. The theory of the ring-shape airfoil was also developed in both countries. Lifting-surface solutions developed by the NACA seem to have had no counterpart in Germany.

The German studies of subsonic compressibility effects on airfoil sections were very similar to ours—for example: (1) in the derivation of accurate potential flows containing a small supersonic region, and in the demonstration that such flows could not be derived above a certain Mach number, (2) in the accurate computation by the Ackert* method of the compressible flow about a Joukowski† airfoil, (3) in efforts to strongarm solutions for airfoil flows with shocks, and (4) in the computation of extensive tables of hypergeometric functions for use in compressible-flow computations. Their experimental high-speed section data, of which a considerable amount was obtained, was similar to that obtained in the NACA 11-inch and 24-inch high-speed tunnels, and largely followed the pattern of the previously published work from these tunnels except that they also put great effort on the development of interferometry for the quantitative study of flow fields. Although the Germans recognized the importance of scale effect, somewhat less effort seems to have been made than in this country to check results in large high-speed tunnels or in flight.

WINGS AT TRANSONIC AND SUPERSONIC SPEEDS

In the development of wings for use at transonic and supersonic speeds, considerable theoretical and experimental work was done on airfoil sections and planforms both in the United States and Germany.

Airfoil section.—Early in the development of low-drag airfoil sections in the United States, it was realized that not only would these sections have low drag at low speeds but would have improved aerodynamic characteristics at high speeds because of lower induced velocities than possessed by conventional sections. Consequently, a family of airfoil sections was finally derived which had satisfactory low drag and considerably improved high-speed characteristics as indicated by low- and high-speed wind-tunnel tests, respectively. Sections such as these were used on two American airplanes, the P-51 and A-26, in operational use in the European war. In Germany some theoretical and experimental work was done in the development of low-drag and high-speed airfoil sections, although the work was not as extensive or systematic as the American development. The German research indicated that some of the older or conventional NACA high-speed sections had fairly satisfactory high-speed characteristics and were apparently content in using them in practically all of their installations. Research in both countries indicated that the Mach number at which large changes in lift, drag, and pitching moment occurred depended not only on the Mach number at which local velocity of sound was first attained but also on the type of pressure distribution. In

*Jacob Ackert, Federal Technical Institute, Zurich

†N. E. Joukowski, professor of mathematics, University of Moscow, author of a classic theory of lift

addition, it was clearly evident in both countries that the conventional airplane was limited to a maximum Mach number of 0.85 to 0.90 because of the loss of lift, rapid rise in drag, and stability and control difficulties at high Mach numbers.

Wing planform.—Late in the war it was recognized in the United States, as a result of theoretical and experimental research, that wing planform had a more pronounced effect on aerodynamic characteristics at high speeds than airfoil section. It was shown by tests at transonic speeds that by decreasing the aspect ratio the compressibility barrier, as evidenced by loss of lift, rapid rise in drag, and large changes in pitching moment, could be delayed to Mach numbers over 0.90. Both theory and experiment at transonic and supersonic speeds indicated that large sweep of the leading edge of a wing (either forward or rearward) would result in delaying and minimizing these compressibility effects to speeds well above the speed of sound. Research in Germany during the war on effects of wing planform was rather extensive and covered a large variety of wing shapes. Near the end of the war in Europe, Germany had an experimental airplane flying with wings designed on the basis of the sweep theory, and practically all of their proposed high-speed airplanes and winged missiles included swept lifting surfaces.

This extensive German research was confined by limitations of wind-tunnel techniques to speeds less than about 90 percent of the speed of sound. Thus, the important transonic region where important changes of aerodynamic characteristics occur was left virtually unexplored by the Germans. Late in the war period the NACA developed techniques to obtain data in this region by means of freely falling bodies and by means of small models mounted in the high-speed flow induced about airplane wings. These unique methods permitted the NACA to obtain data on wings and wing-body configurations continuously through the speed of sound. New wind-tunnel techniques developed by the NACA also permitted data to be obtained very close to the speed of sound. Data obtained by these new methods and by the more recently developed NACA techniques of rocket-powered bodies are laying the foundation of knowledge necessary for the development of airplanes to fly at and above the speed of sound.

BODIES

At moderate subsonic speeds, the aerodynamic characteristics of bodies of relatively large fineness ratio such as generally used in aircraft fuselages are not critically dependent on body shape, provided that there are no abrupt changes in longitudinal profile. The information generally available at the start of the war was adequate and little further research has been done either in Germany or in America. A great deal of theoretical and experimental research on the effects of modifications to basic body shapes such as cockpit canopies, gun turrets, engine cowlings, and the like has been accomplished by the NACA. As far as is now known, comparable German work was limited to development studies for specific designs.

In the transonic speed range, from 0.8 to 1.2 times sonic speed, the NACA has developed a new testing technique by which the drag of test bodies is determined by dropping them from aircraft at high altitudes. The readings of instruments in the bodies are telemetered to test equipment on the ground. Results of the first of these tests, published in 1945, indicated large variations in flow characteristics near sonic speed and showed that drag reductions can be effected in this speed range by increases in fineness ratio. More recently similar results have been obtained with rocket-powered test bodies. No known fundamental research in this speed range was accomplished in Germany.

At supersonic speeds, body drag varies greatly with shape and fineness ratio. Theoretical studies made by NACA during the war have resulted in the development of methods for calculating the lift, drag, and moment characteristics of slender bodies of revolution with or without air inlets. Supersonic wind-tunnel tests made during the war verified the theoretical results. Original data from systematic wartime investigations of supersonic projectile shapes in Germany and Italy became available to the Committee in 1944. These data were analyzed and published by the NACA. Italian theoretical predictions of the nose profile for minimum drag were verified by these test results. A great deal of supersonic development work on specific projects such as the V–2 missile was accomplished in Germany. However, attempts to obtain fundamental aerodynamic data of general usefulness from these specific projects have been disappointing.

The aerodynamic interference that occurs when two or more aerodynamic bodies, such as wing and fuselage, are combined has been the subject of extensive investigation both in America and in Germany. This problem is of critical importance in the transonic and supersonic speed ranges. No adequate theoretical methods are yet available to aid in the prediction of interference effects in these speed ranges. A large amount of data for specific designs has been obtained in both America and Germany. The German work included several preliminary studies of wing-body interference for swept wings. Similar but more extensive investigations are now under way in America.

STABILITY AND CONTROL

Both in this country and in Germany, the importance attached to stability and control investigations is shown by the amount of research performed and the large percentage of test facilities devoted to this work. In order to compare the contributions of the two countries, the subject will be considered under headings based on the flight-speed range concerned.

(a) *Stability and Control at Low Speeds or Beyond the Stall.*—A large amount of wind-tunnel research has been conducted in both Germany and the United States on special control devices, such as spoilers, intended for use on airplanes equipped with high-lift devices to provide low landing speed. Both countries encountered the same basic problems of control lag and ineffectiveness, and arrived at the same solutions, which consist of suitable spoiler design and location. Flight tests were made in both countries on low-speed research airplanes equipped with special high-lift flaps or boundary-layer control. The problem of adequate lateral control was not completely solved for the airplanes employing boundary-layer control. The results of the research on spoiler controls for use with full-span flaps in the United States were embodied in several service airplanes, whereas in Germany these devices were not generally adopted by the manufacturers.

The spin-recovery problem was studied in both countries by means of free-spinning tests of models in vertical tunnels. Both countries arrived at criteria for use by the designer in providing satisfactory spin recovery.

Stall-warning devices utilizing pressure differences over the airfoil were perfected in both countries.

(b) *Stability and Control in the Normal Flight-Speed Range.*—An important development made during the war by the NACA was the determination of a set of specifications for satisfactory flying qualities of airplanes. These specifications placed a measurement of stability and control characteristics in flight on a quantitative basis. These specifications were based on complete measurements of the flying qualities of 20 airplanes and were later substantiated by similar measurements on about 30 additional airplanes. These requirements were adopted by the Army and Navy for the purpose of selecting airplanes with desirable stability and control characteristics for combat and service use. A similar set of specifications for desirable handling qualities was prepared in Germany, but these specifications were based on complete tests of only five airplanes and partial tests on a number of others. The German specifications were never adopted as a standard by the German Air Forces but were merely set up as recommendations to guide the designers and manufacturers of military airplanes.

In order to provide satisfactory flying qualities for airplanes in the design stage, procedures were perfected both in the United States and Germany for wind-tunnel testing of powered models of complete airplanes. These tests were generally conducted on all new airplane designs. In addition, theoretical or empirical methods were developed in both countries to calculate the contributions of various parts of the airplane to its stability.

Theoretical work on the dynamic-stability characteristics of aircraft was conducted extensively in both countries. The number of separate investigations conducted in Germany along these lines appears to exceed the number conducted in this country. However, the main factors contributing to dynamic lateral and longitudinal stability were discovered in both countries and the means determined for avoiding troublesome problems, such as control-free oscillations, were the same in both countries. Other problems of dynamic stability encountered in the tactical operation of aircraft, such as the towing of gliders, were thoroughly investigated in both countries.

A solution of the problem of providing desirably light control forces on large and high-speed airplanes was found to be very important by both countries in order that satisfactory military types could be produced. For this reason a large amount of wind-tunnel testing was conducted to develop satisfactory types of control-surface balances. In this country this program amounted to making separate wind-tunnel tests of the control surfaces of practically every airplane that was designed for possible military use, in addition to numerous tests of generalized aircraft components investigated from the standpoint of fundamental research. A similar course appears to have been followed in Germany. In the United States the mass of data accumulated has been summarized and correlated in several summary reports so that it is now available for use by the designer. The correlation of German work does not appear to have progressed to such an extent, probably because of the less centralized organization of their research laboratories.

The development of servo controls both aerodynamic and mechanical types was given increasing emphasis in both countries towards the end of the war. The theory of such devices was well understood in both countries but the German designers appear to have made freer use of these mechanisms in actual service airplanes than did the American designers.

(c) *Stability and Control at the Highest Speeds Reached by Conventional Aircraft.*—The onset of adverse effects of compressibility on the stability and control characteristics of airplanes was first observed in high-speed dives of fighter-type airplanes. Wind-tunnel and flight tests were conducted in both countries in order to study the reasons for the diving moments and high control forces encountered in these high-speed dives. No satisfactory solution to these problems for service-type airplanes was found by the Germans. In this country, however, dive-recovery flaps were developed which provided a temporary solution. Distortion of the tail surfaces and control surfaces under air loads was found to be partially responsible for many of the difficulties encountered in high-speed dives, and the theory explaining these effects was well developed in both countries. Theories were also worked out to estimate the loss in aileron control due to wing twist at high speeds. The equality of achievement of the United States and Germany in the field of stability and control is shown by the fact that the maximum diving speed reached by aircraft was approximately the same in both cases. This maximum speed was limited by stability and control difficulties rather than by limitations of performance characteristics.

(d) *Stability and Control in the Transonic Speed Range.*—Investigation of the stability and control of airplanes at transonic speeds became important with the development of jet-propelled aircraft capable of traveling at these speeds. Conventional wind tunnels were found to be unsatisfactory for measuring characteristics of airplanes in this speed range. Considerable stability and control research at high supersonic speeds was conducted by the Germans for application to missiles, but they had failed to develop any means of obtaining information in the important transonic speed range. Two methods were developed by the NACA for conducting tests in the transonic speed range. In one of these methods, known as the wing-flow method, small models are mounted in the high-speed flow above an airplane wing in flight. In the other method freely falling models are dropped from high altitudes and they exceed the speed of sound in falling. Methods for obtaining data from these falling bodies by means of radar and telemeter equipment have been developed in this country. Preparations to build research airplanes capable of flying at transonic speeds were made in both countries at the end of the war. In Germany these airplanes employed sweptback wings which had been shown theoretically to present the possibility of improving stability and control characteristics in the transonic speed range. The beneficial effects of sweepback were discovered at the NACA independently at a later date but not in time to prevent [sic] sweptback wings to be applied to the first research airplane designed for transonic flight.

(e) *Stability and Control at Supersonic Speeds.*—Stability and control of missiles traveling at supersonic speeds were studied extensively in Germany in several small supersonic wind tunnels. Great emphasis was being placed on the development of many types of supersonic missiles and several large supersonic tunnels were in preliminary operation or under construction at the end of the war. In addition, some missiles designed for supersonic speeds had been constructed and tested. In this country practically no data on stability and control at supersonic speeds had been obtained.

Internal Aerodynamics

The differences in the strategic requirements for American and German aircraft resulted in considerable differences in the types of internal aerodynamic research conducted by the research organizations of the two countries. In the United States, major emphasis was placed on the solution of specific internal-flow problems confronting long-range aircraft powered in most cases by conventional reciprocating engines. An appreciable portion of the research effort of the NACA was allotted to the development of installations for jet-, turbine-, and rocket-propelled aircraft and to internal-flow systems suitable for transonic and supersonic flight only when it became apparent that the new forms of prime movers could be perfected in time to be useful for the war effort. In Germany, on the other hand, a large percentage of the research effort was allocated throughout the war to the development of jet-propulsion and rocket installations for very fast short-range aircraft and to the development of induction systems suitable for supersonic aircraft and missiles.

Cooling and heat exchangers. The NACA cooling-correlation method was adapted for use with multicylinder aircooled engines during the war years and was further extended to cover the case of the liquid-cooled engine. This method was successfully utilized in the development of the engine installations for numerous military airplanes, thereby substantially shortening the usual troubleshooting development periods. German literature reveals that engine-cooling difficulties continued throughout the war to be one of the principal factors delaying the service use of their new aircraft.

The NACA conducted a number of projects leading to the refinement of aircraft heat exchangers and the evaluation of the factors governing their performance. Comprehensive design charts were developed to aid the cooling-system designer by simplifying selection procedures and permitting the rapid determination of the effects of design compromises on cooling performance. The NACA heat-exchanger research on the whole was confined largely to conventional production-type units. The Germans, however, in addition to similar work, expended considerable effort in the development of tailor-made units for specific airplanes and in research on unconventional arrangements such as the regenerative cooler.

Compressors and Turbines

In the decade before the start of the war, the Germans made numerous important contributions to the aerodynamics of compressors and turbines including the development of theoretical methods for calculating the 2-dimensional characteristics of cascades or rows of blades, and the development of cascade testing techniques and methods of correlation of cascade and rotating-machine performance data. During the war, however, their aerodynamic progress appears to have been limited to relatively minor improvements resulting from development work on specific installations. At the close of the war, the aerodynamic design of the German compressors and turbines still closely followed prewar practice. Examination of the mechanical details of German gas turbine engines reveals that important advances were made in construction techniques and production methods. Advances were also made in the development of blade-cooling methods during the war.

Utilizing the cascade testing technique, the NACA has conducted a fundamental, systematic, pressure-distribution investigation of compressor-blade shapes. This work was guided by the general principle that local velocity peaks on the blades should be avoided, in order to minimize friction and separation losses and to delay compressibility effects. This work resulted in design charts from which efficient shapes and optimum blade settings can be obtained for a wide range of compressor-design parameters. Low-speed tests of these blades in rotating machines have indicated that important gains in pressure rise per stage and in efficiency can be realized by their use. Theoretical work carried on during the war has recently culminated in a greatly improved method for computing the flow about 2-dimensional cascades of compressor and turbine blades.

Conventional axial-flow compressors are limited to a relative blade Mach number of about 0.8 because of the occurrence of shock losses at higher speeds. It is theoretically desirable, however, to operate at higher speeds in order to produce higher compression ratios. The Germans made two attempts during the war to construct a supersonic axial-flow compressor. The first of these attempts ended in destruction of the machine, and the second produced a very low efficiency and only slightly higher pressure ratio than was obtainable from subsonic compressors. The NACA has been working on supersonic compressors since 1942, starting with stationary tests in supersonic jets in which methods were developed for minimizing the shock losses. Continuing this work, a single-stage machine has been designed, constructed, and tested. In its present preliminary stage of development this machine has comparable efficiency, slightly larger mass flow, and a compression ratio four to five times as large as any previous single-stage axial-flow compressor. The knowledge gained from this experimental compressor should lead eventually to smaller, lighter, and more powerful turbojet engines.

PROPELLER RESEARCH THEORY

Both the NACA and German theoretical propeller research during the war period was devoted primarily to development of improved methods of application of the existing theory and relating these applications to design procedures in the form of simplified selection and design charts. In both cases this work eliminated a major portion of the tedious calculations formerly required. The NACA work in this respect was somewhat more complete than the German work in that it included all the important variables in propeller design while the German work did not completely include the effects of design camber and blade width. The German work, on the other hand, was more extensive in the development of theories for the use of shrouds with propellers so that the volume of technical information from the NACA and German work was about the same.

Analytical work in compiling information available from the experimental results and theoretical results bearing on the design of efficient high-speed propellers was carried out more extensively by NACA than by the Germans. The smaller amount of German analytical work is directly traceable to the lack of experimental high-speed research on propellers and propeller-airfoil sections.

PROPELLER SECTIONS

During the war no fundamental research was performed by the Germans directed toward the attainment of improved propeller airfoil sections. The Germans used in the design of their propellers NACA 24-series sections, which are considered one step removed in the development of optimum propeller sections. The NACA on the other hand undertook an extensive propeller-airfoil development program which resulted in optimum critical-speed airfoil sections having low drag characteristics (NACA 16-series sections). The development of these airfoils supplied sections for use in propeller design which delayed the onset of compressibility effects to an important extent. The low-drag characteristics of these airfoil sections produced higher propeller efficiency.

Both the NACA and German work included an extensive amount of experimental testing to determine at high speeds the characteristics of airfoils suitable for use in the design of propellers. The volume of technical information was about the same magnitude.

HIGH-SPEED INVESTIGATIONS

No significant amount of German research on propeller characteristics was performed at high speeds during the war period. It appears that the German research effort on propellers was based upon use of available low-speed information to obtain their propeller designs which, when in production, were to be used throughout the remainder of the war without further change. The NACA, on the other hand, in recognition of the advances of high-speed requirements of propellers occasioned by the war efforts initiated an extensive program of high-speed propeller research. This work was directed toward the procurement of information necessary for the design of efficient high-speed propellers suitable for absorbing increased amounts of power. Propeller dynamometers for the Langley 8-foot high-speed tunnel and the Langley 16-foot high-speed tunnel were designed and constructed. At the same time, dynamometer equipment for Flight Research was also developed.

Propellers were obtained from this research which had efficiencies of from 90 to 95 percent through a speed range up to approximately 500 m.p.h. These efficiencies of these propellers are 7 percent greater at low speeds and 22 percent greater at 500 m.p.h. than could be obtained with conventional propellers in extensive use during the war period. The NACA propellers were free from adverse compressibility effects at speeds approximately 100 m.p.h. in excess of speeds at which serious effects were encountered with conventional propellers available during the early war period. These conventional propellers had essentially the same performance as the German propellers. The adverse effects of compressibility on propellers at high forward speeds were defined in these investigations for the first time. Extensive studies of the effects of propeller shanks on the performance on propellers were made at high speeds and changes in design camber, blade width, and pitch distribution were evaluated.

SWEPTBACK PROPELLERS

The German research pioneered the use of sweep in propellers to effect delays in the onset of compressibility effects. These results showed for the first time that the use of sweep in propellers resulted in delays in the onset of the effects of compressibility. However, the best sweptback propellers developed by German research were less efficient, even at high speeds where the adverse compressibility effects occurred, than the high-speed propellers evolved by the NACA research.

POWER PLANTS

Power plant development in Germany during the war period was in general quite comparable with that in the United States, but differed in detail as the result of differences in military situation, thought, and manufacturing conditions. The Germans, envisioning a greater need for high speed than great power or long range, devoted a much greater proportion of their efforts to development of jet and rocket power plants, and correspondingly less to reciprocating engines. As their military situation deteriorated, the development became a frantic effort to obtain performance advantages, and the newer power plants were put into service in the state of incomplete development.

The German philosophy of reciprocating-engine design favored the use of relatively high compression ratio and low supercharger pressure boost, perhaps due to a lack of high-performance superchargers. To engines of this type the shortage of high-octane fuel was an especially serious handicap, which the Germans met to some extent with the adoption of fuel-injection type engines. In the United States, which was ahead of the Germans with turbo- and multi-stage superchargers, engine outputs were greatly increased as a result of fuel and engine research. As a consequence in the field of high-powered reciprocating engines, with which much of the war was fought, German development lagged by approximately a year.

Jet-propulsion research was well under way in the United States at the start of the war, the NACA having conducted full-scale tests of a unit early in 1942. Due to difference in the military situation, jet-power-plant development was not given as much priority here as in Germany, but rapid advances were made. Possession of superior materials gave the United States a marked advantage, and German designs reflected this situation. Military necessity forced Germany to early production of jet engines, whereas the United States, which possessed lighter, more efficient, and more durable units had not swung into large production at the cessation of hostilities.

The turbine-propeller power plant on which the Germans had been working since before the war advanced about equally in both countries, neither of which succeeded in bringing this important type of unit into production.

The intermittent ram jet used to power the buzz-bomb was a German development not matched by similar research in this country. The steady-flow ram jet, or Lorin duct, on the other hand was the subject of basic research by the NACA at the start of the war. However, in Germany ram-jet research was prosecuted with great rigor as contrasted with low priority in this country.

Liquid-fuel and powder rockets for assisting takeoff developed, and in use, here and in Germany were strikingly similar in design and principle, although there were differences in propellant preferences. Design of rocket-propeller airplanes, started in Germany before the war, resulted in the ME–163, capable of phenomenal speed but so limited in range that it was not regarded by the Germans themselves as especially practical. It was in the field of long-range rocket missiles that the Germans made the most progress. Although the United States had by no means neglected rocket development in its application as a power plant for long-range missiles, the Germans had investigated and overcome many of the practical problems, and several important types had been brought into production.

Viewed as a whole, Germany contributed most in the development of long-duration high-powered liquid-fuel rocket and the ram jet, whereas the United States made greater advances in power, reliability, and weight reduction of reciprocating power plants. In jet and turbine engines, developments were about equal, with Germany getting into production earlier, but with the United States leading in power, weight reduction, reliability, and economy.

MISSILES

At the ending of the War, the Germans had successfully developed and operated subsonic ground-to-ground missiles, the V-1. They had also successfully developed several subsonic ground-to-air, air-to-ground, and air-to-air missiles but had insufficient time to get them into action. They had developed also a wingless supersonic artillery-type missile, the V-2. In addition to these accomplishments, intensive research was under way on stability, guidance, and aerodynamic problems of supersonic interceptor-type missiles.

At the corresponding time in America, although guided missiles presented a significant picture from the military viewpoint, most of the research effort had been directed toward providing superior inhabited aircraft with increasing but still small expenditure of effort on the guided missile. Because of this difference in emphasis, no strict comparison between American and German missile research can be drawn. In the fields such as high-speed aerodynamics, automatic control and stability, and launching, comparison can be made even though progress on the latter two items was not essential to victory.

Aerodynamic research was pursued with the utmost vigor in Germany and America throughout the war since it is the basis for air supremacy in both the missile and aircraft operations. Work in Germany emphasized the use of numerous supersonic wind tunnels, while in America high subsonic tunnels were pushed to a high state of refinement. In addition, in America flight methods were devised for extending aerodynamic information through the transonic speed range (speeds from about 700 to 1000 miles per hour) where the inherent physical restrictions of wind tunnels prevent their use. The Germans had devised no means for aerodynamic research in this transonic speed range, a fact which is now realized would have greatly inhibited their further progress with winged missiles and man-carrying aircraft as well. Work in the German supersonic tunnels was devoted largely to reduction of drag, problems of high moment changes, center of pressure shift, lift and control effectiveness, and damping derivatives in roll, pitch, and yaw. This work was in the category of initial exploratory work and showed some of the difficulties which had to be overcome but offered few of the solutions to these difficulties. The benefits of sweepback were discovered several years earlier in Germany than in America but, by the end of the war, American information on sweptback configurations was equal to and, in the transonic range, surpassed that possessed in Germany. Neither country, however, had successfully used sweptback wings to increase aircraft or missile speeds in actual operations.

American work on automatic stability was done largely in conjunction with Army and Navy glide bombs and with controlled bombs such as the Azon and Razon. This work proceeded on a sound theoretical basis so that corrective measures for difficulties observed in flight tests were quickly applied.

Automatic stability and control theory was also sufficiently advanced to permit quick adjustment of the American version of the German V-1 and, in the closing months of the war, U.S. Army tactical trials of this weapon showed performance surpassing that achieved by the Germans although the military and naval situation did not require its use. Similarly, a zero-ramp launching technique was devised for V-1 missiles which would permit mobile launching stations in contrast to the massive steam ramps used for the German operations.

39. "Report of the Director of Aeronautical Research submitted to the National Advisory Committee for Aeronautics at its annual meeting, October 23, 1947."

[Hugh L. Dryden succeeded George Lewis as Director of Aeronautical Research in September 1947. In this, his first formal report to the Main Committee, he outlined his goals and impressions. The subtle changes he introduced would lead to a more rational functioning of the overall NACA research program through increased utilization of the technical committees, greater emphasis on basic research, and faster dissemination of research results to meet the needs of industry.]

I have the honor to submit herewith my first report to the Committee as Director of Aeronautical Research. In the seven weeks that I have served you in this capacity, I have made a beginning in the large task of becoming familiar with the activities under way at the three laboratories. I have made courtesy calls at the plants of a few aircraft manufacturers, and I have taken part in the Budget Bureau hearings on our estimates for the coming fiscal year. The next few months will continue to be a period of education for me. I consider myself very fortunate to have the benefit of guidance from Dr. Lewis, and I am happy to say that the entire staff has given me its wholehearted support and cooperation. The Associate Director, Mr. Crowley, and the Executive Secretary, Mr. Victory, have not only been ready to give me background information and express their views on the problems arising from day to day, but they have also kindly relieved me of much administrative routine.

One of the first tasks which I have set for the staff and myself is a better formulation of the Committee's research programs. The principal tool at present for recording and keeping track of the research programs is the research authorization, of which there are hundreds, and the job orders, of which there are thousands. The usual lists of investigations requested by the military services, and of the contracts with educational institutions approved since the last meeting, have been distributed to you. These serve the useful purpose of enabling one to trace the history of a particular task, but are not useful instruments for the control of general research policy which I consider to be the function of the Main Committee and the standing technical committees. I believe that our research programs must be formulated and examined from various points of view and studied in the light of their environment, i.e., the international situation, the current state and objectives of aeronautical development, and developments in basic scientific research in physics, chemistry, and engineering.

At this stage in my study I can only illustrate by specific examples what I have in mind. The urgency of aeronautical research results from the relation of air power to national security. Aircraft having the highest speed dominate the air. The development of the turbo-jet engine during the last war made available a large amount of power in a small package, and thus paved the way for the attainment of much higher flight speeds than possible with reciprocating engines and propellers. It is clear that there is no upper limit to the possible speed of aircraft. The nation that makes the best research effort to develop the new power plants and explore the problems of high-speed flight can lead the world in air power. That nation must be the United States.

In this environment one of the objectives of present-day aeronautical development is the attainment of horizonal flight of a piloted aircraft propelled at supersonic speeds for long distances. It is the duty of the NACA to provide for the military services and the industry, the basic data on aerodynamics and propulsion to make piloted supersonic flight, not only possible, but safe and reliable. A large part of the Committee's research effort is directed toward this objective. The apex of this effort is the flight research on high-speed research airplanes at Muroc, California, conducted by the military services, the aircraft industry, and the NACA in cooperation. This type of organized effort has been extremely successful and valuable, so much so that the headquarters staff and I are studying the possibility of a similar procedure for expediting and focusing research effort on power plants of the future. It is gratifying that the flight tests have as yet shown nothing which was not predicted from wind-tunnel, wing-flow, and rocket tests of models.

Another large segment of the Committee's work relates to the transport airplanes of today and the near future, in particular, to their general handling characteristics and flying qualities, their comfort and safety in normal flight, in flight in rough air, and in emergency landings on land and sea.

Other work is applicable to all aircraft, to improve their performance, and to study the application to them of improved wing sections, controls and of such new developments as boundary-layer suction.

For budget and accounting purposes work under such general objectives is broken down into 19 research programs relating broadly to research on the airplane itself, to its power plant, and to operating problems. Programs in transonic and supersonic aerodynamics, stability and control, and loads, began about 1944, and have grown to a considerable magnitude, accounting for the fact that our budget estimates are higher now than during the war years. Since supersonic aircraft must also operate safely at subsonic speeds, and since they require new wing sections and wing plan forms, a large fraction of the subsonic work conducted at present is devoted to supersonic aircraft.

A typical large area of work in this field is on wing plan forms. From theoretical considerations and limited experimental data, three general types of plan forms have advantages in various high speed ranges. These are the sweptback and sweptforward, the low-aspect-ratio, and the triangular. The general objective of the NACA work in this area is to determine the properties of these plan forms over a wide range of Reynolds and Mach numbers so that the designer may have the basic data from which to make the best choice for a particular design intended to accomplish a specific purpose.

One segment of this area of work is that relating to a specific triangular plan form selected in the light of present theory as best for a specific design Mach number.

The power-plant work in 1944 was mainly on reciprocating engines, whereas today the work is largely on jet engines. Considered in relation to the major goal of the supersonic flight of piloted aircraft, the NACA program of flight-propulsion research breaks down into the major divisions of turbo-jet and turbo-prop, rocket, and ramjet. In each of these divisions there is a two-fold goal—(1) to obtain increased performance for a given size and weight, and (2) to increase the reliability and life. These goals are ever-receding ones as development progresses, but there are certain landmarks, for example, the fuel economy of reciprocating engines, which research workers believe will ultimately be obtained with turbo-jet engines.

Let us consider the program for turbo-jet engines in greater detail. To increase the performance of the complete power plant for a given size and weight, the same goal must be set for each of the components, i.e., compressor, combustor, turbine, bearings; the components must be matched to secure the optimum performance of all components under the same conditions; and the operating variables must be suitably controlled. Considering a single component, the turbine, specific avenues of research are open including aerodynamic improvement of the blade design, and operation at higher gas temperatures either through cooling of the blades and rim or through the use of materials capable of withstanding higher temperatures such as improved metal alloys, ceramics, or mixtures of the two. The solution of these problems rests on basic research in aerodynamics, heat transfer, engineering mechanics, properties of materials, etc.

In a similar manner the goal of increased reliability and life leads to studies of blade stresses, vibration and flutter, disc failures, and icing protection.

Having broken the program down into specific problems (research authorizations or job orders) to be attacked by individuals or small groups, it is necessary to integrate the results and study their application by research on complete power plants. It has been the policy of the Committee to do such research on power plants under development by the armed forces and industry, and intended for large-scale procurement. In this way there is great incidental benefit in securing early application of the research results. However, designers must be somewhat conservative in the development of such power plants because the armed services must secure tactically useful power plants.

In addition to this type of breakdown of the research programs stemming from the practical goals, there is need for another which begins with the state of knowledge in the basic sciences. Such work lays the foundation for the future and opens the way to more rapid accomplishment of the detailed tasks arising from our general objectives. The Committee has already taken steps in its estimates to provide facilities for basic research in the field of extremely high altitudes and high speeds, and already has under way many specific research tasks arising from this type of breakdown of the research program.

It is quite obvious that the ramifications of an adequate research program are so great that no single individual can master or guide the details. The technical staff of the Washington Office has been increased, and we have asked for a further increase in the 1949 Budget. I believe that it is your function to determine the general policy as to the objectives of research in relation to aeronautical development and air policy. Through the standing technical committees, the technical goals in specific fields are reviewed in the light of general objectives, and recommendations made to you. The programs for particular areas within these technical fields are then reviewed in detail by the subcommittees of our standing committees. The programs as approved by the Main Committee are carried out by the Director of Aeronautical Research and his staff.

In my conversations with the top officials of aircraft companies, great stress was laid on the need for the prompt dissemination of information, and the Committee was complimented for improvement in this respect. I believe that the groundwork has been laid for still further improvement. The establishment of an index system for all reports, the publication of abstract cards with the reports, and the use of the memorandum report make the results more promptly available and more useful. The best means of rapid transmission of information so far found is the technical conference of relatively small groups of experts in a relatively narrow field. Many more of them will be held. The next one scheduled is that to be held at the Ames Laboratory on November 5 and 6 to inform the designers of military aircraft of the latest information of use in the design of transonic airplanes.

There are many other matters of general policy to which I have given some thought and which I will discuss with you from time to time. I have been asked to express my personal views with regard to aeronautical research and government policy before the President's Air Policy Commission. Copies of my statement have been distributed to you. They should be kept confidential until released by the Commission.

40. "Functions and Responsibilities of Standing Committees and Subcommittees of the National Advisory Committee for Aeronautics," 1 Jan. 1950.

[When Hugh Dryden succeeded George Lewis as the NACA's director of aeronautical research in 1947, he resolved to strengthen and clarify the role of the technical committees (see document 39). This policy statement is one result. Most of Dryden's concepts had been in effect, at least nominally, throughout most of the NACA's history, but this is the first formal statement of what the technical committees were to do and how. Note the attention given to the issue of industry "representation." (See document 43.)]

The National Advisory Committee for Aeronautics was established by the Congress in 1915 and consists of 17 members appointed by the President of the United States to include the heads of the U.S. Air Force, naval aviation, Civil Aeronautics Administration, National Bureau of Standards, Weather Bureau, and Smithsonian Institution, together with scientists and aeronautical experts. A Chairman and a Vice Chairman are elected annually. The Committee is authorized to conduct research and experiment in aeronautics in such laboratories as may be placed under its direction, and to encourage and support research in scientific and educational institutions by means of research contracts. To discharge this responsibility the Committee has a technical staff, headed by a Director, operating three major research stations, and has organized standing committees and subcommittees (referred to hereafter as technical committees) with advisory functions with respect to various fields of aeronautical research. The entire organization is usually also referred to as the NACA. To avoid confusion in this discussion the Committee of 17 men is called the Executive Committee.

The Executive Committee performs the same function in NACA as does a Board of Directors in private industry. The Committee has the power and responsibility to determine programs and policies, and to arrange for their execution. To assist in planning, the Executive Committee appoints annually the technical committees composed of groups of experts in various fields of aeronautics. The military and civil air organizations of the Government are also represented on the technical committees. While these technical committees have the status of advisory groups, their competence and prestige are very high and their recommendations within their field of competence are almost certain to be adopted.

Members of technical subcommittees appointed by the NACA from outside the Government are appointed in their professional capacities as individuals and not as representatives of their employers. They (members) are expected, as opportunity is given by the normal contacts of a professional man, to discuss technical matters with their professional colleagues within their own and other organizations as required in the planning of NACA research programs. In order to promote free discussion, the meetings of the subcommittees are closed; accordingly, the minutes are confidential documents and are made available only for the use of a subcommittee member and his immediate staff. The subcommittee members from the military services and from other Government agencies are representatives of the offices with which they are affiliated, but the members not representing Government agencies are not representatives of any organization.

The Director is appointed by the Executive Committee. The Director and his staff operate the three major research stations and two field stations, and in addition supply technical and secretarial assistance to the technical committees. The Director is ex officio a member of all technical committees, and members of his staff are included in their membership. Hence the Director and his staff have a direct channel for the presentation of research proposals originating within the staff and for presenting their views to the technical committees.

The present committees (January 1950) are as follows:

- Committee on Aerodynamics
  - Subcommittee on Fluid Mechanics
  - Subcommittee on High-Speed Aerodynamics
  - Subcommittee on Stability and Control
  - Subcommittee on Internal Flow
  - Subcommittee on Propellers for Aircraft
  - Subcommittee on Seaplanes
  - Subcommittee on Helicopters
  - Special Subcommittee on the Upper Atmosphere
- Committee on Power Plants for Aircraft
  - Subcommittee on Aircraft Fuels
  - Subcommittee on Combustion

Subcommittee on Lubrication and Wear
Subcommittee on Compressors
Subcommittee on Turbines
Subcommittee on Propulsion-Systems Analysis
Subcommittee on Heat-Resisting Materials
Committee on Aircraft Construction
Subcommittee on Aircraft Structures
Subcommittee on Aircraft Loads
Subcommittee on Vibration and Flutter
Subcommittee on Aircraft Structural Materials
Committee on Operating Problems
Subcommittee on Meteorological Problems
Subcommittee on Icing Problems
Subcommittee on Aircraft Fire Prevention
Industry Consulting Committee

The duties of any specific technical committee are to consider problems relating to the assigned field, for example, propulsion of aircraft and guided missiles, and to make recommendations to the Executive Committee for their study. In order to discharge their duties the technical committees are instructed periodically to

1. Review research in progress by the NACA and by other agencies.
2. Recommend problems that should be investigated by the NACA or by other agencies.
3. Assist in the formulation and coordination of programs for research by the NACA and by other agencies.
4. Serve as a medium for the interchange of information regarding investigations and developments in progress or proposed.

Problems to be investigated by the NACA may be suggested by the Director and his staff, by members of one of the technical committees, by the military services, other Government organizations, and in fact by any individual or organization. Authorization for inclusion of a research problem in the program of the NACA is given by the Executive Committee in the form of an approved Research Authorization. All research to be conducted by the NACA with public funds requires the approval of the Executive Committee. With the exception of investigations requested by Government agencies, it is the policy of the Executive Committee to obtain recommendations from the appropriate technical committees on all proposed research, although such referral is not mandatory. It is also the policy of the Executive Committee, in so far as practicable, to keep the technical committees informed of the program in their fields so that their recommendations may be intelligently made.

The Research Authorizations describe research problems for which solutions are needed. The attack on these problems requires detailed planning, the assignment of responsibility to laboratory groups, the determination of equipment to be used, scheduling of work, etc. These matters are the responsibility of the Director and his staff. Members of the technical committees are often requested to advise on methods of attack, and on aspects of particular investigations, and are encouraged to make recommendations in these areas. The technical committees are, however, not expected to perform administrative functions in the execution of approved research programs.

January 1, 1950

41. Ira H. Abbott, memorandum, "Improvement of Laboratory Inspections," 14 June 1949.

[Ira H. Abbott went to NACA headquarters in 1948 after almost two decades at Langley. Familiar as he was with the old industry conferences, which were discontinued for security reasons as World War II approached, and sensitive as well to the intent behind the postwar laboratory inspections, Abbott attempted in this memorandum to provide guidelines for uniform and effective inspections. The new inspections had even more show and less substance than the old Langley conferences; substantive exchanges of information were restricted almost exclusively to "classified technical conferences" on specific topics. In the margin of the original, John Victory wrote "Good" beside the last paragraph in section 4 and "Excellent" beside the second half of section 5; he wrote "Fine statement" at the end of the memorandum.]

1. Although the recent Langley inspection is considered to have been highly successful, it has resulted in several thoughts about possible improvements for future inspections. It is recommended that these thoughts, and others that may exist, be discussed in this office and their substance transmitted to the laboratories for general guidance.

2. *Purpose.* The inspections are held to acquaint leaders of the aviation industry, military establishment, other Government agencies, educational institutions, and others interested in aeronautics, with the research and facilities of the NACA. Within limits set by classification, the visitors should get a general impression of the state of knowledge and of the contributions of the Committee, but the purpose of the inspections is not to present our latest technical information. This latter purpose is served by classified technical conferences and by regular reporting procedures.

3. *Status.* Current inspections appear to be in a transitional stage between the old engineering conferences and the type of inspection that will best serve the present purpose. Although the talks have been simplified and generalized to some extent, there is still a tendency to present too much detailed technical information. Comparatively few of the visitors are technical experts. Moreover, aeronautics has become so complex that even capable technical men cannot be expected to grasp quickly the intricacies of the many subjects discussed during a single inspection. The visitors can be expected to carry away only a general impression. The inspections should be conducted so that this impression is not one of bewilderment, but rather one of confidence that the Committee knows its business and is making substantial progress through the orderly but vigorous conduct of research in well-planned facilities.

4. *Generalization.* Each talk or series of talks should, if possible, cover a well-defined technical problem. The nature and origin of the problem, its importance and relation to the aircraft or power plant as a whole should be briefly but adequately covered. In many cases a brief history of the problem, consisting of only a few sentences, may help to orient the listener. The talk should explain the status of the problem, the research attack that is being made on it, and the nature of recent contributions. One or more examples of recent contributions should be shown and explained without being too technical.

Visitors will tend to form impressions from the general character of the talks and subject matter. They will not usually understand or heed subtle qualifications. Erroneous impressions may, therefore, result from talks that are strictly accurate. Much misunderstanding can be avoided by plain statements that claim enough, but never too much. Any necessary qualifications should be straightforward and unmistakable.

5. *Simplification.* Care should be taken to make all talks and charts understandable to people unfamiliar with technical terms. Even such terms as Reynolds number and Mach number are not generally understood, or may be improperly understood. Al-

though such terms need not, and probably should not, be avoided altogether, understanding of the material presented should not depend upon the visitors' knowing their meaning. Such terms as shock wave, normal shock, expansion zone, Mach lines, boundary layer, and rotary derivatives are not generally understood and require some explanation; perhaps only a few words. The visitors cannot be expected to know the meaning of symbols, even the most common ones. Words should be used instead of symbols or to supplement symbols on charts for identification of scales, and other purposes. Formulas should generally be avoided, although simple ones may be useful on occasion.

No more than one idea should be presented on a single chart. Such devices as pictorial representation and bar charts should be used freely to avoid the appearance of complexity. The use of symbols or other complicated methods for identification of curves should be avoided. Although simplified, the charts should present quantitative results for the benefit of those who understand their significance when the classification and nature of the subject permits. Ingenuity will be required to simplify the presentation without losing the technical significance.

6. *Demonstrations.* As a general rule, every stop should include some form of demonstration or inspection of equipment. The visitors expect and enjoy demonstrations. Moreover, demonstrations create more lasting impressions than lectures that may be imperfectly understood. Whenever possible the visitors should see facilities or apparatus in operation rather than stationary exhibits.

7. *Staff.* All division chiefs, section heads, and other technical staff taking part should understand the purpose of the inspection and the necessity for presenting the material in a simple, effective manner. The best result will be obtained only by everyone's working toward the same goal.

IRA H. ABBOTT,
Aeronautical Consultant.

42. "NACA Policy on Release of Proprietary Information," adopted by the NACA 16 June 1949, amended 16 Dec. 1949.

[Since 1931 (see document 25), the NACA had reserved to itself the right to release proprietary information obtained in the course of doing research for private parties. Orville Wright took exception to the policy then (see document 26) and many industry representatives had since. In 1949, the NACA gave in to industry pressure and adopted the policy reproduced here. (See also document 43.)]

In the interest of fair and equitable consideration of a manufacturer's competitive position, it is the policy of the NACA to withhold from release, except to appropriate government agencies and the manufacturer concerned, technical information on specific models of a manufacturer's aeronautical product undergoing active development, except by specific agreement with the manufacturer.

With regard to technical information on specific models that have reached the production stage or whose development has been discontinued, the NACA will observe the following procedure:

(1) Reports containing such information will be made available to the manufacturer concerned for review and comment in advance of circulation beyond government agencies.

(2) When reports containing such information are distributed beyond government agencies, the NACA, upon request, will provide the manufacturer concerned with the list of organizations and individuals to whom the report has been sent, in

order that the manufacturer may supply such supplementary information as he desires.

(3) When the NACA contemplates the formal presentation orally of such information in advance of its release in report form, the manufacturer concerned will have the opportunity to review and comment on the proposed discussion.

43. "A Report to the Industry on the Work of the NACA Industry Consulting Committee," 30 Dec. 1949.

[Unlike the NACA technical committees, whose industry members did *not* serve as representatives of their companies, the Industry Consulting Committee was explicitly designed to bring within the NACA structure representatives who could voice the concerns and interests of the entire aviation industry, though not necessarily of the specific companies that employed them. This ICC report reflects the range of issues considered by the committee, the tenor of its recommendations, and the strength of its influence on NACA policy. (See documents 36, 40, and 42 for evidence of changes in NACA policy prompted by the ICC.) As might be expected, relations between the NACA and the ICC were occasionally more strained than this glowing report suggests.]

The NACA Industry Consulting Committee, which was established late in 1945, has as its objective the promotion of the understanding of the mutual policy problems of the industry and the NACA, as distinguished from detailed technical problems. The Industry Consulting Committee has been active in expressing the industry's viewpoint on those problems referred to it by the NACA and has brought to the attention of the NACA those problems arising in industry relating to NACA work. It strives to assure the continued excellent cooperation that exists between the industry and the NACA in ever seeking to advance the frontiers of flight.

While the Industry Consulting Committee has been working closely with the NACA, having met with the NACA on several occasions in addition to its own meetings, it has in the past relied principally on personal contacts and correspondence in advising the industry of its work. In view of this, the following report has been prepared in order that the industry may have a better understanding and a full appreciation of the work of the Industry Consulting Committee.

ORGANIZATION

Late in the fall of 1945, the National Advisory Committee for Aeronautics established the Industry Consulting Committee to "advise the NACA as to general research policy and programs especially with regard to the needs of industry." By statute the membership of the Committee comprises the presidents of four firms making aircraft engines or large aircraft, the presidents of two airlines, the president of one firm making light aircraft, and one representative of fixed-base aircraft operation. In December 1949 the NACA increased the size of the Committee to nine by authorizing the addition of a member chosen from the presidents of firms manufacturing aircraft engines or aircraft accessories. The members are appointed annually in order to provide rotation of membership and the Committee elects its chairman and vice-chairman annually from its membership. Dr. T. L. K. Smull, Head, Research Coordination of the NACA, serves as secretary for the Committee.

By mutual agreement with NACA and the other groups concerned, the Industry Consulting Committee has used the technical committees of the Aircraft Industries Association and the Air Transport Association for such technical advice as required on airframe, engine and air transport matters. In addition, it has been the practice for the Chairman to circularize company presidents in advance of the meetings of the ICC to determine topics of interest to the Committee that otherwise might not have come to their attention.

WORK OF THE INDUSTRY CONSULTING COMMITTEE

National Aeronautical Research Policy—One of the first problems considered by the ICC was in connection with the drafting and approval of a policy on aeronautical research that would be nationwide in scope. The Aeronautical Research Policy of the NACA was studied by the ICC and suggestions offered regarding the relationship of the industry to government. This study, both by the NACA and the ICC, culminated at a joint meeting of the ICC with the NACA on March 21, 1946, with all parties concerned agreeing that the Aeronautical Research Policy, as revised on March 21, 1946, be approved as a National Aeronautical Research Policy for the guidance of the Army, Navy, the CAA, the NACA, and the aircraft industry.*

Recommendations regarding the Organization and Operation of the NACA Committee Structure—One of the first recommendations of the Industry Consulting Committee dealt with membership of the NACA, when it was recommended that the NACA should have at least three public members as follows: one member technically qualified in current airframe problems, one member technically qualified in current aircraft power plant problems, and one member technically qualified in current problems in the operation of civilian aircraft. At the time this recommendation was made, the NACA had one member actively engaged in the field of operation of civilian aircraft. Since then, as vacancies occurred in the NACA, men were appointed whose backgrounds met the other qualifications set forth in the ICC's recommendation.

The ICC, since its inception, has stressed the desirability of keeping NACA technical committees small enough that they would not become unwieldy but at the same time has stressed the desirability that the number of men chosen from industry be increased.

It has also been brought to the attention of the NACA that it would be highly desirable for those members chosen from industry to serve on NACA technical committees to speak with authority in their field regarding progress and work of the NACA. At the same time, it was felt that the most effective operation of the NACA technical committees would result if the ICC would make available to the NACA suggestions as to men in industry they considered most competent in the various fields covered by the NACA technical committees. With these ideas in mind, at its December 2, 1948 meeting, the Industry Consulting Committee passed the following resolution:

> RESOLVED, That the Industry Consulting Committee recommends that the NACA adopt the following policy in the interest of improving the operation and efficiency of the NACA subcommittees in planning aeronautical research in the national interest:
>
> (a) With a view toward obtaining the best information possible regarding industrial specialists who are qualified and available for services on various NACA subcommittees, the NACA shall solicit from the recognized industry technical committees of the Aircraft Industries Association a selection of candidates for each subcommittee member that may be selected from the industry. Acceptance or rejection of such recommendations shall be the sole responsibility of the NACA, and such recommendations shall not alter the status of subcommittee members who shall continue to serve as individuals rather than representing the interests of any company, group, or organization.

*See document 40.

(b) In order to promote productive exchange of basic research information relative to planning for existing and future research programs, the NACA subcommittee members shall, within the limits of military security, be (1) permitted by their employers to discuss progress (in their field of specialization) such as shall not compromise their employer's competitive position, (2) permitted to discuss with other specialists in the industry information reviewed in NACA subcommittee meetings to the extent that such discussions are in the interests of furthering the basic research program.

The NACA, following its study of these suggestions, at its December 16, 1948 meeting, revised the appropriate section of the statement of "Functions and Responsibilities of Standing Committees and Subcommittees of the NACA," in such a manner that the ICC feels that part (b) of its resolution was fully covered. . . .*

Members of technical subcommittees appointed by the NACA from outside the Government are appointed in their professional capacities as individuals and not as representatives of their employers. They (members) are expected, as opportunity is given by the normal contacts of a professional man, to discuss technical matters with their professional colleagues within their own and other organizations as required in the planning of NACA research programs. In order to promote free discussion, the meetings of the subcommittees are closed; accordingly, the minutes are confidential documents and are made available for the use of only subcommittee members and their immediate personal staffs. The subcommittee members from the military services and from other government agencies are representatives of the offices with which they are affiliated, but the members not representing government agencies are not representatives of any organization.

Part (a) of this resolution was discussed by the ICC with the NACA at a joint meeting on May 19, 1949, at which time the NACA indicated they would welcome a roster of qualified and available people in whom the industry has confidence and who would be available for subcommittee services and suggested that the ICC proceed with the preparation of such a list to be submitted annually not later than October. The ICC, with the assistance of the AIA, has prepared the first of such rosters and submitted it to the NACA on September 28, 1949.

The ICC is firm in its belief that the industry should encourage its personnel who serve on NACA technical committees to take a more active part in their NACA subcommittee work. It should be noted that the industry expects a lot on the part of the NACA and that the industry should in turn recognize its responsibility to the successful operation of the NACA. In keeping with this the ICC at its May 19, 1949 meeting, adopted the following resolution:

RESOLVED, That the Industry Consulting Committee recommends that the aircraft industry recognize their responsibility to contribute to the successful operation of the NACA by encouraging their personnel that serve as members of NACA technical committees to devote the time and effort required to most effectively carry out the duties and responsibilities of membership on an NACA technical committee.

Recommendations regarding the Exchange and Dissemination of NACA Research Information—Since the ICC was established, at a time when there was a major change in emphasis being made in the NACA research program, brought on not only by the practical application of jet propulsion, but also by the return of the NACA to more fundamental research in lieu of the development work it has been carrying on during the war for the military services, the ICC expressed the desire for a comprehensive report in some detail by the NACA to the industry regarding the proposed NACA program to enable

*See document 44.

the industry to prepare thoroughly studied and correlated recommendations. In response to this, the NACA, in August 1946, circulated throughout the industry a summary of the NACA's research effort. It was reviewed in detail by the industry and the results, in the form of comments submitted by the AIA, were most helpful. The comments and recommendations of the industry in various phases of the Committee's activities were reviewed by the technical committees of the NACA and were of material assistance to these groups in their ever continuing re-examination and formulation of the NACA research program. At the same time, the ICC recommended that the publication policy of the NACA be revised to eliminate as far as possible the delays inherent in the release of reports and that frequent progress reports by the NACA be made available for those that need the information. It also noted the desirability of military declassification of information developed by the NACA during the war in order that this information might be made available to the greatest possible extent at the earliest possible date. In this regard, it should be noted that the NACA has reorganized its report duplication procedure, which greatly reduces the time required for the preparation for release. The declassification of information developed during the war was rapidly effected and a comprehensive index of all NACA technical publications was prepared and widely distributed throughout the industry in 1947. These indexes are now being revised and brought to date. These new indexes will be released early in 1950.

The Industry Consulting Committee also urged that there be more frequent contact between NACA staff members and industry technicians and it has been gratifying to note that the number of visits by NACA technical personnel to industry has increased substantially during the past several years. In this regard, to be most effective, the industry in turn should permit and even foster more visits by its highly trained technical personnel to the NACA.

For the past several years, the question of the possible release of a manufacturer's proprietary information by the NACA in its reports has received considerable attention by the ICC. This had been of particular concern in the phase of the NACA research on aircraft engines and engine components. The question has been reviewed and discussed in detail by the ICC as well as by the groups relied on by the ICC for technical advice. The consideration of this problem was culminated by the ICC at its December 2, 1948 meeting when it passed the following resolution:

> RESOLVED, That the Industry Consulting Committee recommends to the NACA the following policy considerations for adoption in the interest of improving the manner of circulating reports and engineering information resulting from development or evaluation testing of an individual manufacturer's product conducted by the NACA:
>
> (a) A fair and equitable policy on the distribution of engineering data on a manufacturer's product should include provisions for prior review by the manufacturer of any reports of NACA testing on his equipment to determine whether or not the design information of a proprietary nature in the report will be detrimental to his competitive position.
>
> (b) Such policy should also provide for the right of the manufacturer to modify or supplement the NACA report in order to insure there is no conflict with patent or design rights.
>
> (c) Such policy should also provide for prior review by the manufacturer of any proposed public discussion by the NACA of information resulting from development or evaluation testing of a manufacturer's product to assure that such public discussion will not present design information of a proprietary nature that would be detrimental to a manufacturer's competitive position.

This recommendation was reviewed by the NACA and discussed in detail at the meeting of the ICC with the NACA on May 19, 1949. Final action was taken by the NACA at its December 16, 1949 meeting. . . .*

In its study of present NACA procedures for the dissemination of research information by (a) correspondence, (b) visits, both by industry personnel to the NACA and by members of the NACA staff to industry, (c) NACA technical conferences, (d) NACA reports, both the annual reports on NACA research and status reports on research in a given field, (e) inspections held at the NACA laboratories and (f) meetings of NACA technical committees, the Industry Consulting Committee felt that one further step should be made by the NACA in the interest of effective cooperation between the NACA and the industry. It was pointed out that the present urgency in connection with the aircraft program was such that it was necessary not only for the industry to have the results of completed research but also to have knowledge of research in progress so that when problems arose in industry, the industry could quickly relate them to NACA research in progress for the purpose of arranging discussions by industry personnel at the NACA laboratories. With this in mind, the Industry Consulting Committee at its May 19, 1949 meeting, passed the following resolution:

> RESOLVED, That the Industry Consulting Committee recommends that the NACA keep the aircraft industry advised of the research in progress in the Committee's laboratories by means of a listing and brief description of active investigations, prepared and distributed at convenient intervals.

This was discussed with the NACA at that time and the NACA is now working on the problem of preparing a suitable status report of active research for distribution to the top engineering personnel in industry. It is anticipated that the first of these status reports will be distributed in the near future.

Unitary Wind-Tunnel Plan—The Industry Consulting Committee has been kept advised by the NACA of the steps that were being taken regarding the preparation of a unitary wind-tunnel plan for the transonic and supersonic facilities that would be required in the national interest. Title I of public law 415, 81st Congress, approved October 27, 1949, authorizes the NACA and the armed services to initiate this wind tunnel program. In that regard, the scope of the facilities included in this authorization is in keeping with the recommendations that were made to the NACA regarding the program by the ICC at a joint meeting with the NACA on June 5, 1947.

General—It has not been the purpose of this report to discuss in detail all of the problems that have come to the attention of the Committee, but rather to give an indication of the scope of the Committee's activities and to give an indication of its accomplishments. The ICC has found the NACA to be both willing and cooperative in striving to achieve a greater understanding of the problems of the industry. The Committee would like to emphasize that it feels that industry in turn must not be negligent in its responsibilities toward the effective operation of the NACA. If the ICC is to continue as an effective advisory group to the NACA, it must have the continued confidence and support of the industry. . . .

44. "Policy for Operation of Unitary Wind Tunnels on Development and Test Problems of Industry," approved by the NACA 6 May 1953 on recommendation of the NACA Panel on Research Facilities.

[The language of the National Unitary Wind Tunnel Plan Act of 1949 technically reduced the NACA to a housekeeping function for unitary tunnels built on industry's behalf at NACA laboratories. In the event, however, the unitary plan proved to have

*See document 46.

exaggerated supersonic wind-tunnel requirements; even after meeting all the legitimate demands of industry, the NACA staff had ample time available for its own projects in the unitary tunnels. This pattern was evident by the time the NACA, in consultation with the industry and the military services, prepared this policy for unitary-tunnel operation. The NACA resisted industry pressure to charge fees on contract work done for the military services, a practice that would have benefited the industry with no advantage to the government.]

Public Law 415, 81st Congress, states in the section which authorized the construction of unitary wind tunnels at NACA laboratories that:

> "The facilities authorized by this section shall be operated and staffed by the Committee but shall be available primarily to industry for testing experimental models in connection with the development of aircraft and missiles. Such tests shall be scheduled and conducted in accordance with industry's requirements and allocation of laboratory time shall be made in accordance with the public interest, with proper emphasis upon the requirements of each military service and due consideration of civilian needs."

The following policy recommended by the NACA Panel on Research Facilities was adopted by the National Advisory Committee for Aeronautics at its meeting on May 6, 1953:

1. The unitary wind tunnels shall be operated in the public interest with the desires and requirements of industry fully considered and their rights adequately protected.
2. Development work shall be given first priority in these tunnels, but the NACA staff shall be given the necessary flexibility to permit utilization of the unitary wind tunnels and other NACA equipment for the greatest public good.
3. Different treatment shall be given (a) company-financed proprietary development projects and (b) development projects of companies carried out under military contract.
4. A fee covering total direct costs shall be charged for proprietary work (3a above).
5. Proprietary work shall be scheduled on a first-come-first-served basis, subject to rules that safeguard against monopolization of wind tunnel time by any single company or group.
6. A certain amount of time shall be reserved each year for proprietary testing, the amount to be determined by experience. Initially 60 days per year, or as much thereof as required, shall be allotted for proprietary testing for each unitary wind tunnel.
7. No fee shall be charged for work on projects carried out under military contract (3b above).
8. Scheduling of projects of companies having military contracts or letters of intent shall be carried out substantially as at present. All such projects shall be approved by one of two clearance panels before scheduling. The clearance panels shall consist of one representative each from the Air Force, Navy, and NACA, competent to determine military priorities in the use of NACA facilities. The existing panel shall be continued as the Aerodynamics Clearance Panel and a second Propulsion Clearance Panel shall be appointed. The routine scheduling of specific dates shall be done by the NACA staff.
9. In all development testing, military and non-military alike, the manufacturer shall be given the greatest possible freedom within the objectives of the scheduled program to obtain the precise information he requires, to determine the sequence and number of test runs to be made, and to make modifications to

the program arising from the results currently being obtained, subject only to requirements of safety and practicability and the total time assigned.

10. In order to recommend to the Executive Committee of the NACA detailed rules and procedures within the preceding policy framework, a unitary committee shall be established, composed of seven members, one each from the Air Force, Navy, CAA, and NACA, and three from industry. This composition is chosen to give industry a predominant voice as compared with any single Government agency but not over all Government agencies combined. When the rules and procedures have been recommended, the unitary committee shall meet only if and when there are new problems of an important nature to be considered. The members shall be so chosen that the committee will be competent to cover both aerodynamic and propulsion wind tunnels.

11. It is considered desirable that the rules and procedures developed by NACA for operation of unitary wind tunnels be coordinated with corresponding ones of the military services so that the greatest practicable degree of uniformity is established in the methods and operations of tunnels throughout the unitary plan. It may even be expedient to utilize the same unitary committee and clearance panels.

The report of the NACA Facilities Panel upon which the above policy is based was prepared following an all-day hearing at NACA Headquarters on March 6, 1953, at which representatives of the aircraft industry and of the Air Force, Navy, and NACA presented their views to the Panel and responded to questions. The Panel members are:

J. H. Doolittle, Chairman
Rear Admiral Thomas S. Combs, U.S.N. (represented at the hearing by Rear Admiral Lloyd Harrison, U.S.N.)
Ronald M. Hazen
Major General Donald L. Putt, U.S.A.F.
Arthur E. Raymond
Walter G. Whitman
Theodore P. Wright

The witnesses who appeared before the Panel were:

Hugh L. Dryden (NACA)
Colonel E. H. Wynn, U.S.A.F. (Air Research and Development Command, U.S.A.F.)
F. A. Louden (Bureau of Aeronautics, U.S.N.)
Admiral DeWitt Ramsey, U.S.N., Ret. (Aircraft Industries Association)
Major General E. M. Powers, U.S.A.F., Ret. (Curtiss-Wright Corporation)
A. T. Colwell (Thompson Products, Inc.)
C. L. Johnson (Lockheed Aircraft Corporation)
Ralph S. Damon (Chairman, Industry Consulting Committee, NACA)
Kendall Perkins (McDonnell Aircraft Corporation)
Robert L. Hall (Grumman Aircraft Engineering Corporation)

John F. Victory served as secretary and recorded the proceedings.

Comment is made on paragraph 7 of the policy. Even though most of the industry representatives who were heard by the Panel strongly supported a fee system for work on projects under military contract, the Panel recommended against a fee for such work, and the NACA concurred, for the following reasons:

(a) Since the costs of all investigations of this nature are paid for by the Government, there is no useful purpose to be served by requiring the company to pay a fee which the company in turn recaptures from the military service that has contracted for the development.

(b) Since by law fees from a non-governmental agency are required to be deposited in the U.S. Treasury as miscellaneous receipts and are not available for expenditure by NACA, the net result of a fee system for military contract work would be to reduce, at least by the amount of the fee, the funds available to the military services for research and development. This would not be in the public interest nor in the interest of any of the parties concerned, including industry.

(c) The fee system for military contract work involves unnecessary bookkeeping and overhead as the fee has no bearing on the scheduling or conduct of the investigation. The military services, the industry, and NACA would be involved in sizeable estimating and accounting activities, quite unproductive and all definitely tending to increase the cost of aircraft and missiles to the taxpayers. NACA keeps cost records on all projects and can supply such information when required.

(d) The fee system would not adequately appraise the concurrent interests of the military services and the public in work done under military contract. Under the system adopted, these interests are recognized in the determination of the amount of time to be allotted to any specific military project. Consideration is given to the program desired by the contractor, the priority attached to the project by the contracting agency, the programs of the other military services and of other contractors, existing data, and the ability of the equipment to provide the desired information. The interests of all parties involved are protected by joint discussions in advance of scheduling.

45. "A National Research Program for Space Technology," a staff study of the NACA, 14 Jan. 1958.

[While the Eisenhower administration was pondering the shape of the American space program in the early days of 1958, the NACA published its bid to become the national space agency. Or rather it proposed to continue its pattern of cooperation with industry and other government agencies, expanding its activities to encompass spaceflight and space research. The NACA would soon be chosen as the nucleus of a new civilian space program, but its transmutation into the National Aeronautics and Space Administration meant that the NACA would be forced to abandon many of the old practices recommended in this document.]

In this technological age the country that advances most rapidly in science will have the greatest influence on the emotions and imagination of man, will have the greatest rate of industrial and economic development, the highest standard of living, and the greatest military potential, and will command the respect of the world. The scientific advances of the Soviets in their bid for world supremacy have been amply demonstrated by the recent success of their satellite program. These advances are the results of a far-reaching plan and sustained effort that poses a most serious challenge to the United States and the Western world. It is of great urgency and importance to our country both from consideration of our prestige as a nation as well as military necessity that this challenge be met by an energetic program of research and development for the conquest of space.

This task requires rapid extension of knowledge in regions already familiar, and penetration into still unexplored areas. Major research fields include the following:

Space Mechanics
Space Environment

Energy Sources
Propulsion Systems
Vehicle Configuration and Structure
Materials
Launch, Rendezvous, Re-entry, and Recovery
Communication, Navigation, and Guidance
Space Biology
Flight Simulation
Measurement and Observation Techniques

A major, coordinated national effort is required for rapid and efficient execution of these researches. Urgency dictates the maximum effective utilization of existing facilities, knowledge, and organizations.

The possibilities opened up by space flight and its impact on the thinking of mankind are so vast that scientific research in the field should not be guided only by considerations of military application. Conversely, the urgency for fulfilling military needs demands that the research should be strongly influenced by military considerations. It is accordingly proposed that the scientific research be the responsibility of a national civilian agency working in close cooperation with the applied research and development groups required for weapon-systems development by the military.

The pattern to be followed is that already developed by the NACA and the military services. The NACA is an organization in being, already engaged in research applicable to the problems of space flight and having a great many of the special aerodynamic, propulsion, and structures facilities required, and qualified to take prompt advantage of the technical training and interest of scientists competent to help in the research on space technology. The membership of the NACA and its broadly based technical subcommittees includes people from both military and civilian agencies of the government, and representative scientific and engineering members from private life, thus assuring full cooperation with the military services, the scientific community, and industry. This organization has proved to be an effective national research and coordinating body.

This type of cooperation and coordination among equals, which is traditional with the NACA, is considered to be essential. The broad scope of the scientific research to be accomplished will require the active cooperation of many governmental and private organizations. The alternative to cooperation would be an undesirable concentration of research authority which would hamper the initiative and the freedom of thought on which science lives.

During the past half century this country achieved world leadership in solving and later exploiting the problems of flight. The NACA in partnership with the military services, other branches of the government, the scientific community, and industry has played a leading role in this achievement. The accomplishments of the NACA are known and envied by aeronautical research establishments of all the larger countries of the world.

The NACA is an experienced operating agency with great research laboratories and a favorable reputation among scientists for its effective sponsorship of basic research in other institutions through research contracts. Since the end of World War II the NACA has been increasingly engaged in research applicable to the problems of space flight and has designed and constructed the special facilities required for this work. The NACA in 1952 formally initiated studies "of the problems associated with unmanned and manned flight at altitudes from 50 miles up and at speeds from Mach number 10 to the velocity of escape from the earth's gravity," a result of which is the cooperative NACA–USAF–USN project, the X–15 research airplane designed and now under construction for studying some of the problems of manned flight in nearby space.

The Soviet challenge to our leadership is of such scope and vigor, however, that our rate of progress in solving the problems of space flight must be greatly increased. The NACA is capable, by rapid extension and expansion of its effort, of providing leadership in space technology.

Adequate response by the NACA to this responsibility will require a rapid expansion of its efforts. A rational procedure for this expansion is proposed as follows:

1. Greatly expanded use of our applicable existing facilities through rapid increase in staff.
2. A greatly expanded contract research program to obtain assistance from groups outside the government which possess singular competence in specific areas of interest.
3. Construction of needed new research facilities at existing laboratories and at new locations when required.

As in the past, the NACA will need to supplement and complete its laboratory findings by flight research. The capability will be needed to make space flights for research purposes. This will require a launching site and an appropriate network of observation stations.

In addition to the research fields previously enumerated as directly connected to the problems of space flight, an adequate national program must provide for basic scientific research on the phenomena of the upper region of the atmosphere and space. These include the character and distribution of matter, cosmic rays, solar radiation, electric, magnetic, and gravitational fields, and scientific studies of the universe from satellites and space platforms. The National Science Foundation and the National Academy of Sciences should be responsible for the planning of scientific experiments and the assignment of priorities for research on space phenomena for basic scientific purposes. In order to avoid confusion and unnecessary duplication of facilities, the responsibility for making space flights for this scientific research should rest with the NACA. It would be the duty of the NACA to provide the flights and to assist in all possible ways in obtaining the required data, but financial support of the basic research programs should rest with the National Science Foundation.

There exists a continuing need for large-scale flight effort on the frontiers of space technology, using special research vehicles of advanced design. Cost considerations alone make it impractical to separate the scientific aspects of such effort from the military aspects. A cooperative effort is required. Consequently, these flights should be conducted by the appropriate agencies of the Department of Defense and the National Advisory Committee for Aeronautics in the successful pattern of the research airplane programs.

46. "A Program for Expansion of NACA Research in Space Flight Technology with Estimates of the Staff and Facilities Required," 10 Feb. 1958.

[In this document, the NACA projected how it would carry out the space mission that the Eisenhower administration was about to hand it. The analysis is remarkably prescient on propulsion, launch vehicles, and spaceflight, demonstrating those strengths within the NACA organization that made it the logical choice as nucleus of the new space agency. Section 4 is furthest from the mark; the capabilities envisioned for this new laboratory were realized by expanding existing NACA laboratories and acquiring facilities like those of the Development Operations Division of the Army Ballistic Missile Agency at Redstone Arsenal, which became NASA's Marshall Space Flight Center. NASA would never pursue nuclear propulsion research as extensively as envisioned in this prospectus. The sections on contracting and budgeting proved to be exceptionally conservative, and space science was almost totally slighted.]

Section I

INTRODUCTION

At a meeting of the National Advisory Committee for Aeronautics on January 16, 1958, a resolution was adopted on the subject of space flight which is reproduced on the inside of the cover of this document. The resolution states in part "that the National Advisory Committee for Aeronautics has an important responsibility for coordinating and for conducting research in space technology either in its own laboratories or by contract, and therefore should expand its existing program and add supplementary facilities to those now available as necessary."

As a guide to implementing this resolution the NACA staff has studied the elements of an expanded research program on space flight and has prepared estimates of

(1) the increase in staff and facilities required at the existing NACA laboratories,

(2) the nature and scope of supplementary facilities and staff that are required at a new laboratory, and

(3) the expansion of contract research by the NACA.

Recognizing "the urgency of an adequate national program of research and development leading to manned satellites, lunar, and interplanetary flight" the study was directed to achieve maximum augmented research capability at the earliest possible date.

Since the end of World War II the NACA has been engaged increasingly in research applicable to the problem of space flight and has designed and constructed some special aerodynamic, structural, and propulsion facilities required for this work. For example, studies were formally initiated in 1952 leading to the X-15 research airplane project, a cooperative project between the NACA, the Air Force, and the Navy. The North American Aviation Corporation is now building the X-15 and it is scheduled to make its first flight in about one year. The X-15 will be used to explore problems of manned flight into nearby space, particularly the control of the attitude of the vehicle in space in the absence of aerodynamic forces, the safe return from space to the atmosphere without destructive heating, and the effect of weightlessness on the pilot. The NACA is also engaged in studies of satellite configurations suitable for safe re-entry at still higher speeds, both for manned and unmanned flight.

The research program of the NACA has evolved in the past several years so that over ⅔ of the existing staff will be engaged in researches applicable to advanced missiles and space vehicles in fiscal year 1959. A strong core of research leadership exists in the NACA staff in many of the most critical areas of space flight technology. This study therefore envisions expansion of the NACA staff and facilities under this research leadership at the highest rate consistent with the hiring of qualified personnel. In program areas in which singular competence exists in scholastic or other scientific groups outside the NACA staff, such groups would be integrated into program through the research contracts.

Prototype, and in some cases, large-scale facilities required for space flight research exist now at the NACA laboratories. As the new staff is acquired it can be integrated, trained, and usefully employed in the space flight program, while new and advanced facilities are under construction.

Supplementary facilities will be located at existing laboratories whenever possible in the interests of speed and economy of effort. A new laboratory will be required at a site appropriate for the launching of space vehicles. Systems research on flight vehicles and on space propulsion devices will be conducted at the new flight laboratory. This laboratory would also provide a site for rocket and nuclear propulsion research facilities that cannot be located at existing laboratories for reasons of safety and required exclusion distance.

A major expansion of the NACA flight research program is proposed. Currently many of the problems of space flight are studied without requiring that the space vehicle be launched into an orbit. The technique for these space-equivalent flights is well established; they can be augmented quickly and economically without major technical or facility developments. Concurrently, the flight of unmanned satellites can be rapidly accomplished with extension of the instrumentation and range capabilities of the existing launch site. Propulsion and guidance for these flights can be provided by equipment already developed as a part of the military program.

In logical continuation of such an orderly program, larger unmanned satellites can serve as test beds for research in space on energy sources, propulsion systems, materials, structures, etc. New launching facilities would be required for these vehicles.

The goal of the program would be to provide basic research in support of the development of manned satellites and the travel of man to the moon and nearby planets. At each step the program would not only serve to advance the technology of space flight but would provide space vehicles for carrying instruments in support of national scientific groups investigating the phenomena of the upper atmosphere and of space. For research on large and complex space systems a cooperative program with the military services and industry, similar to the current X-15 program, will be required.

In the following sections, the proposed program of NACA research on space flight, and the staff and facilities required to implement it, are discussed under the following outline headings:

1. Energy Sources and Propulsion Systems
2. Materials and Structures
3. Launch, Rendezvous, Re-entry, Recovery, and Flight Simulation
4. Measurement, Communications, and Guidance
5. Space Mechanics
6. Space Environment

SECTION II

THE RESEARCH PROGRAM

ENERGY SOURCES AND PROPULSION SYSTEMS

For flight beyond the earth's atmosphere, research is required to ensure the most efficient utilization of energy sources that can yield the high thrust required for vehicle launching or for deceleration in landing, the smaller thrust required for control of speed and direction during flight in space, the high impulse required for propulsion in space, and the power required for communications and for operations within or about the space vehicle.

The high thrust required for launching is probably best provided by chemical and nuclear rockets. The high specific impulse required for very long flights in space is probably best provided by electric power generating plants that operate ion or plasma jets; these power plants can also produce auxiliary operating power. For flights in space of short or intermediate duration (cis-lunar flights, for example), several systems appear competitive: chemical rockets; nuclear rockets, in which the reactor heats a propellant; solar rockets, in which the sun heats a propellant; and ion and plasma jets.

PROPULSION SYSTEMS FOR LAUNCHING

Chemical Rockets

Propellants. Theoretical analyses and small-scale experiments have shown the potential merits of liquid-propellant combinations such as hydrogen-oxygen, ammonia-fluorine, hydrazine-fluorine, hydrogen-fluorine, and hydrogen-ozone for long-range flight. These, capable of providing high impulse per unit mass, yield high ratios of payload to gross vehicle weight. High-energy-release compounds may also be incorporated into solid-propellant rockets. Theoretical performance of such propellants, under all probable operating conditions, must be calculated. The complex analyses require use of high-speed automatic computers, for the analyses must extend to the complete vehicle and its flight missions. Similar analyses must be made of the applicability of free radicals as propellants; use of these propellants is contingent on development of techniques for producing and stabilizing free radicals in high concentrations.

Because of the large quantities of propellant involved in launching very large vehicles, thorough investigation must be made of techniques for on-the-site preparation of the chemicals, for their storage in the liquefied condition (at temperatures as low as −420°F), and for their handling with full protection of personnel and neighborhoods against toxic effect.

Propellant pumps. Effective pumping of low-temperature or highly reactive propellants requires controlling the amount of cavitation, reducing pump weight (pump weights in current design are as much as one half the total engine weight), and providing reliable rotating seals for cryogenic-fluid pumps. Research involves study of pump inlet head requirements and of pump stage characteristics, and evaluation of pumps, first in complete turbopump systems and then in complete vehicle systems.

Combustion. To obtain high combustion rates and efficiencies, it is necessary to study the effects of propellant injection, mixing, and vaporization, of chamber configuration, and of the kinetics of the reaction. It is necessary also to determine causes of and remedies for the destructive combustion oscillations that often accompany high combustion rates. Experimental research must progress from small-scale to full-scale rockets, because scaling laws are yet to be determined. Similar combustion problems exist for solid propellant rockets: ignition, burning rates, temperature, and pressure effects on burning must be determined for various high-energy grain compositions on both a small and a large scale.

Cooling. In the liquid-propellant motor, thrust chamber and nozzle walls are cooled by the propellants; the amount of required cooling is markedly increased by combustion oscillations. The effectiveness of heat transfer is a function of coolant-passage, thrust-chamber, and nozzle design as well as of the propellant. Nozzle-cooling may also be required in high-energy solid-propellant motors. To establish reliable and lightweight designs, theoretical analyses and experimental tests are required on small-scale and, later, full-scale engines.

Turbines and gas generators. It is desirable to operate the turbine on the same high-energy propellants as the rocket itself. It is also desirable that turbine and propellant pump be matched so that they may operate at the same speed. The turbine must also produce the maximum amount of work per pound of working fluid. Research is therefore required to develop satisfactory gas generators and turbines able to withstand high-temperature corrosive gases and to meet the requirements of low weight, low rotational speed, high efficiency, and high reliability.

Controls and systems studies. Research is required on techniques and apparatus for control of flow rates, flow-rate ratios, pressures, heat-transfer rates, and thrust direction in chemical rocket motors. Initial laboratory tests employ electromechanical simulation of such parameters of the rocket motor as chamber-, injector-, and propellant-system characteristics. Later research progresses to tests on small- and large-scale rocket engines.

Nuclear Rockets

The nuclear rocket, with potentially higher specific impulse than the chemical rocket, offers a substantial increase in payload for a given gross vehicle weight. The advantage of higher specific impulse is offset by higher engine weight and by handling difficulties. The goal of nuclear rocket research is to approach the high specific impulse theoretically possible while minimizing the engine weight and the handling problems.

Reactor composition and geometry. (1) Criticality investigation: Existing methods of analysis must be modified, and new methods devised, to treat the epithermal and fast reactors that may be desirable; these methods must be checked by critical experiments. Satisfactory methods can then be used to analyze effects of fuel concentration in various cladding materials, of moderator configuration, of pressure shells and thermal shields, and of reflector materials and configurations on critical loading and on spatial- and spectral-neutron-flux distributions. Desirable reactor configurations can then be designed. Mock-ups of these on a large variable-geometry critical facility are required to determine the necessary fuel loading as well as the variation of neutron flux with position in the reactor and with neutron energy.

(2) Fuel-element research: Some problems in this area are—

(a) fission-product diffusion through fuel-element cladding;

(b) fuel distribution required for a desired power distribution;

(c) maintenance of fuel-element strength and life at high temperatures and high radiation fluxes, by appropriate metallurgical, fabrication, and assembly techniques;

(d) analysis of the steady-state and dynamic heat transfer between propulsion gas and fuel element.

Although each problem may at first be treated separately, research must eventually be conducted under actual reactor operating conditions, because the temperature level, the gradients in temperature, the fuel loading, the neutron flux levels, and the flow rates must all be approximated simultaneously. There are two ways in which this research can be accomplished: by means of a test reactor that can supply the proper neutron flux level, or by a full-scale nuclear rocket test firing. Both approaches must be pursued. Experiments in a test reactor are more economical, but full-scale tests provide a closer approximation to all test conditions and are an indispensable preliminary to any nuclear rocket launching.

Since the required test reactor represents a considerable extension of current reactor technology, a further desirable preliminary step is a test in an already available reactor of lower flux- and power-density.

Reactor control. The neutron flux levels of the reactors intended for nuclear rocket application far exceed values in existing reactors. These high flux levels, in themselves, introduce new control problems. Typical are those that arise from the very rapid response of the xenon burnout rate to a perturbation of neutron flux in thermal reactors, and the low cross-sections possessed by the usual control materials for fast-neutron radiation.

Pumps and turbines. Problems are similar to those in the chemical rocket field, but generally more difficult. The low densities of liquid and gaseous hydrogen enforce use of large pumps and turbines of many stages. An additional problem is the heating of pump and turbine by radiation from the reactor.

PROPULSION SYSTEMS FOR FLIGHT IN SPACE

Chemical and nuclear rockets remain attractive for many types of flight in space. Although launching rockets may be used to furnish sufficient initial impulse so that the vehicle coasts to its destination, a more useful propulsive means may be a low-thrust rocket that is usable for relatively long periods during the flight. Such rockets require long-life engines that are relatively small compared to those used in launching, since only low accelerations are needed. Their higher thrust-to-weight ratio permits shorter travel time to a given rendezvous than do the electrical propulsion schemes; this could be more important than high payload in missions such as rescue operations.

As flight duration increases, the electrical propulsion devices, electric-arc-heated jets and ion and plasma jets, appear superior; these require electric power. The systems which generate this power can also provide the power for auxiliary operations in or about the space vehicle.

Chemical and Nuclear Rockets

Areas requiring research for propulsion in space, as distinguished from launching, are:

Thrust chambers. Low chamber pressure may be desirable for the chemical rockets, since high nozzle pressure ratios are available even for a low chamber pressure. The results are reduction in required weights of engine and propellant systems and alleviation of engine cooling and erosion problems. Undesirable effects may be: (1) combustion inefficiency, since low pressures always reduce chemical reaction rate, and (2) energy losses caused by increased initial dissociation in the chamber and decreased recombination rates in the exhaust nozzle.

The nuclear rocket may realize considerable advantage from the use of low chamber pressure. Here, the increased dissociation of hydrogen at low pressures permits the addition of more enthalpy to the propellant without exceeding the temperature limit of the reactor material. Of course, this means that the reactor flow passages must be designed for low gas pressure; the supporting heat transfer studies must include these conditions.

Exhaust nozzles. To fully expand the exhaust gases to the high pressure ratios encountered in space will require carefully contoured nozzles. The required contours may be significantly different for each propellant system, and must allow for the chemical recombination that occurs as temperature decreases through the nozzle. The recombination effects are much greater here than for conventional high-thrust rockets. Extensive experimental investigation under simulated high-altitude conditions is therefore required.

Propellant tanks and pressurization systems. Lightweight propellant-pressurization systems can replace turbopump systems if low rocket chamber pressures are used. The associated propellant tanks will require thermal radiation shields and refrigeration equipment to permit long-term storage of liquefied gases in space. Design of tanks and of pressurization systems presents unique problems because the tanks may be too flimsy to contain propellant during take-off; they would then require assembly in orbit and filling from supply ships.

Thrust modulation, starting, and termination. Space propulsion will require rocket engines having variable thrust direction and thrust magnitude, and capable of many start-stop cycles for maneuvering to effect rendezvous. The problem of starting chemical rockets under high-vacuum conditions must therefore be studied. This problem, as well as that of thrust termination, may be particularly severe with solid-propellant rockets.

Solar Rockets

Solar energy may be used to heat hydrogen for use as a rocket propellant. For flights of intermediate duration (e.g., cis-lunar ones), such a system appears competitive in weight with a nuclear rocket and superior in thrust capability to an ion or plasma jet. The problems of radiation collection by lightweight, durable surfaces must be solved. A heat exchanger of low weight must then receive this radiant heat and transfer it to the hydrogen, which is then exhausted through a conventional rocket nozzle.

Electric-Arc-Heated Jet

Nuclear fission energy can be converted by a thermomechanical power plant to electric energy. An electric arc can then heat hydrogen for use in a rocket. This system is capable of providing higher specific impulse than is obtained from a nuclear rocket; the specific impulse appears limited by nozzle cooling requirements. Research problems are electrode cooling and erosion, nozzle cooling, and electric power plant design.

Ion and Plasma Jets

For interplanetary travel with high payload-to-gross-weight ratios, propulsion devices are desired which provide a higher specific impulse than that attainable with chemical or nuclear rockets. The optimum specific impulse for any flight mission will, of course, depend on the weight of power plant, shielding, and structure required to produce this impulse. One promising technique for obtaining high values of specific impulse is through electrical propulsion; that is, the acceleration of positive ions or plasmas to very high jet velocities (3×10^5 feet per second, and higher) by electrostatic and electromagnetic fields.

Specific problem areas are:

Ion generation. Various methods of generation must be studied, to determine which method gives high ionization efficiency with low equipment weight. Promising methods are:

(a) contact of propellant having low ionization potential (e.g., the alkali metals) with grids composed of metal having a high work function (e.g., platinum or tungsten).

(b) electron removal from a plasma created by high intensity electrical discharges, electromagnetic induction, or short-wavelength radiation.

In order to reduce weight and size, for a given thrust, attempts should be made to produce ions with high mass-to-charge ratios; e.g., by ionizing high molecular-weight materials or by producing charged multimolecular particles.

Ion acceleration. Thrust per unit jet area is limited by current density, when electrostatic acceleration is used. The saturation current density can be increased if the accelerator length is reduced, but too short a length may result in a scattered ion jet or in electrical breakdown between the electrodes. The geometric designs that may effect the best compromise must be studied; for example, use of a number of small units to produce a given over-all thrust, with the length-to-diameter ratio of each unit sufficiently high to reduce field divergence and jet scattering.

Improved accelerator life and reliability must be sought by studies of electrode heating and erosion and of the application of induced magnetic fields to reduce positive-ion contact with the electrodes.

The extent to which uncharged molecules and molecular particles can be accelerated by positive-ion bombardment must be determined. If the end velocity of the uncharged particles can be made to approach that of the ions, then high ionization efficiency may not be required and a more favorable overall mass-to-charge ratio may be attainable for a mixture of ionized and non-ionized materials.

Space-charge neutralization. The maximum current density that can be obtained in the jet is limited by space-charge effects. To avoid space-charge buildup, electrons must be ejected at the same rate as positive ions and must be made to intermingle with the ions to form a neutral plasma within an extremely short distance of the jet exit. Optimum electron beam configurations must be determined, as well as the best methods of securing maximum neutralization efficiency by use of electric and magnetic fields.

Plasma generation. Electric-arc discharge and electromagnetic induction are two promising means for plasma generation. For electric-arc plasma generators wherein a gaseous propellant is used, research is necessary on electrode materials, spacing, cooling, and erosion. Where the electrode material is to be used as a propellant, research is necessary on feeding of the electrode propellant. Plasma generation by electromagnetic induction requires search for desirable combinations of coil arrangement, peak current, pulsing frequency, and propellant.

Plasma acceleration. A plasma may be accelerated by either externally applied or internally induced magnetic fields. The positive and negative charges comprising the plasma are accelerated without separation, so that space charge is avoided, and thrust for a given exhaust area may be higher than that attainable in the case of ion jets. Pertinent information on acceleration by internally induced magnetic fields will come from research on controlled fusion. Acceleration by externally applied magnetic fields will require high-field-strength electromagnetic coils, and research will be necessary to reduce power losses by efficient coil configuration and by the use of cryogenic coil coolants, with possible exploitation of super-conductivity. Acceleration of plasma to high velocities will also require research on means of producing high-frequency, time-varying magnetic fields positioned along the length of the accelerator. Investigations of segments of full-scale systems combining practical plasma generators, plasma accelerators, and the necessary electrical circuits and generators must be conducted to determine whether troublesome component interactions will occur.

ELECTRIC POWER PRODUCTION

The principal energy sources considered suitable for generation of electric power in space are (1) solar radiation, (2) radioisotopes, (3) nuclear fission, and (4) nuclear fusion. Solar radiation and radioisotopes appear most suitable for producing small amounts of electric power for auxiliary equipment and for sustaining satellites by means of ion or plasma jets. Nuclear-fission and solar energy sources appear most suitable for producing the large electric power required for interplanetary flight by means of ion and plasma jets, and nuclear-fusion energy is potentially suitable.

Solar Radiation

The solar battery is a promising source of less than a kilowatt of electric power. Effectiveness of this device will depend on further advances in the field of solid-state physics; such advances may also provide more efficient thermoelectric energy converters. Thermomechanical processes, like those described for nuclear fission, for converting heat from solar radiation to electric power, must also be investigated. Research must also be directed to methods for construction of low-weight, easily-repaired, radiation-collecting surfaces.

Radioisotopes

Energy from radioisotopes in the form of either radiolytic decomposition energy or heat for thermomechanical devices must be evaluated as sources of electric power. Use of polonium-210 to decompose water now appears especially attractive for less than a kilowatt of electric power; the resulting gaseous hydrogen and oxygen can be recombined in a fuel cell in order to produce electric power. Research should include (1) study of means for sensitizing the reaction in order to increase the yields of hydrogen and oxygen, (2) design of low-weight decomposition chambers and fuel cells, (3) search for more readily available or longer lived isotopes than polonium-210, and (4) search for suitable working substances other than water. Other related schemes, such as the radioelectric cell, should be explored.

The capabilities of the radioisotope-thermomechanical system will be estimated from the results of two other studies: research on the radioisotope fuel cell will guide selection of the suitable radioisotope, and research on the fission-thermomechanical system will supply information on effective conversion of heat to electric power.

Nuclear Fission

A thermomechanical system that uses heat from nuclear fission is considered to hold the highest promise for producing electric power for space propulsion of manned vehicles in the near future. In this power plant, a working fluid is heated in a reactor and is then expanded through a turbine. Waste heat is rejected by thermal radiation from a large radiator, and the working fluid is then recompressed to its initial pressure. The working fluid could be a gas operating in a Brayton cycle; or the fluid could be a liquid that is boiled and condensed in a Rankine cycle. Achieving high performance in such a power plant involves the following problems:

(1) *Choice of gas or vapor as the working fluid.*—A gas cycle permits use of inert gas, like helium, so that higher cycle temperatures are permitted and corrosion of metallic parts is not a serious problem. A metallic-vapor cycle permits about tenfold reduction in radiator size for a given turbine inlet temperature; however, the radiator still has the greatest weight of any component in the power plant. Because of its greater long-term potential, the vapor cycle deserves the primary effort; the gas cycle must be carried along, at a lower level of effort, as a reserve solution in case corrosion problems prove insurmountable.

(2) *Fluid properties.*—The physical properties of promising metals in their liquid and vapor phases must be determined. Typical metals of interest are mercury, rubidium, sodium, and lithium.

(3) *Convective heat transfer* must be investigated for liquid and vaporized metals, particularly during phase change in a zero-gravity field.

(4) *Radiator design.*—Because of its size, the radiator must be as light as possible. Rotation appears desirable to provide (a) a centrifugal field for separation of liquid and vapor phases, and (b) an artificial gravity field for the crew. However, vibration may be excited by the machinery and by unbalances introduced by crew motions; hence vibration damping to avoid structural fatigue must be studied. Meteoroid damage and repair of the thin shell of the radiator must also be considered.

(5) *Corrosion and mass transfer.*—In addition to the usual problems of this type associated with liquid metals, evaporation and condensation produce additional problems. The radiator may gradually dissolve in the working fluid, and the dissolved metal carried to and deposited in the boiler. Long-term tests are required to study this problem.

(6) Serious *radiation damage* to materials near the reactor after prolonged exposure of one or more years must be prevented.

(7) *Crew protection.*—Shielding against radiation from the reactor is helped by the absence of surrounding matter that would scatter radiation, but is hindered by the requirement that shields in space must withstand abnormally high temperatures. New shield materials and new criteria for radiation attenuation are required.

(8) *Fuel-element fabrication.*—Large quantities of uranium or other fissile material are used up in power plants generating several megawatts. Burnable poisons must be investigated in order to extend the fraction of a given loading of U-235 that can be consumed. The stability of the poisons and their compounds in combination with other reactor materials must be studied. Materials and methods must be found for fabricating fuel elements containing unusually high fractions of fuel and poison.

(9) *Reactor design.*—For the large power plant, the high initial loading of U-235 and the high burn-up cause unusual problems. Producing non-uniform energy release through the core, to obtain maximum coolant-out temperature, is another problem.

For power plants of a few kilowatts, reactor-weight minimization becomes more important than uranium burn-up. Novel fast reactors must therefore be designed.

(10) *Generators* must be designed to maintain high efficiency and to minimize weight of the generator and its radiator by operating the generators at high temperatures and high stresses.

(11) *Turbine design.*—The turbine would use unconventional materials, operating for a very long time at high temperature and high stress. The best compromise between weight and efficiency must be established, without compromising reliability.

(12) *Pump or compressor design.*—Pump weight and reliability are the principal considerations in liquid-metal systems; novel compressor design is required in gaseous-helium systems.

Nuclear Fusion

When the methods of initiating, maintaining, and containing the fusion reaction have been developed by laboratories now working on this project, the adaptations to flight propulsion will require (a) basic cycle analyses, (b) minimization of size and weight of electric- and magnetic-field generators, and (c) analytical and experimental work on the practical problems of shielding, heat transfer, and integration with vehicle configuration.

Those aspects of fusion research that are directly applicable to plasma-jet propulsion can be undertaken immediately. These include methods of generating, retaining, and accelerating the plasma, and methods of reducing size and weight of electrical equipment. Advances toward the solution of these problems in either the thermonuclear field or in the plasma-jet field are helpful to both fields. Also, studies of thermodynamic cycles and methods by which fusion can be applied to propulsion must be undertaken, particularly of techniques which will combine thrust and power generation in a single compact unit.

Materials and Structures

Advances in space-flight structures and propulsion systems are critically dependent upon advances in materials and materials fabrication. The goal of developing optimum structures and safe, efficient power plants will best be achieved by integration of a strong materials research program with structural and propulsion research. The required research ranges from basic studies in solid-state physics, through material development and evaluation, to fabrication into useful structures and power plant components.

Materials to Contain High-Energy Propellants

Materials are needed that have high strength over a wide temperature range and that can withstand highly reactive high-energy propellants. For example, fluorine reacts vigorously with virtually all pliable materials, so that the problems of valve seals and turbopump seals become extremely difficult; fluorine also can be contained only in certain metallic containers that are scrupulously clean. At the other extreme of the temperature range, the walls of regeneratively cooled chambers are in contact with rocket combustion gases at temperatures of 5000°-9000° F.

Materials for Nuclear Reactors

Materials for fuel elements and for adjacent structural materials must maintain high strength at high temperatures and in high radiation fields. Required research includes the development of methods for inserting fuel into the fuel element structure, the behavior of fuel elements when nuclear fuel is molten or near molten, and determination of fission product leakage from various fuel elements. Since high burn-up reactors will be used in space flight, the compatibility of reactor poisons with other reactor materials must be determined. For such reactors, where low weight and long life are primary requirements, careful determination is required of the allowable thermal stresses in materials used in fuel elements, pressure shells, and thermal shields.

New criteria for radiation shielding and new shield materials usable at high temperatures are required.

Materials for Heat Exchangers

Stringent requirements exist for materials employed in heat exchangers using the alkali metals as heat transfer media, in both liquid and vapor states. Both steady-state and dynamic conditions must be considered. Thermal conductivity, diffusivity, heat capacity, electrical and thermoelectric properties, and radiant emittance must be determined for various materials and for various material shapes. Additional properties must be measured for the fluids themselves, in both vapor and liquid states: e.g., enthalpy, entropy, viscosity, dimerization, heat capacity lag, surface tension, electrical resistivity, and speed of sound.

Materials for Electrical Propulsion

The properties of superconductors and their fundamental laws of behavior have direct application in magnetogasdynamics, electromagnetic plasma accelerators, and fusion devices. A search is needed for high voltage insulators and for materials with unusual magnetic properties. The ion jet will require high voltage insulators, with high resistance to erosion, for use in the ion accelerator; the arc plasma jet will require electrode materials with very low erosion rates at high temperatures.

Materials and Structures for Solar Energy Collection

Solid-state physics research must develop superior materials for thermoelectric and for photoelectric conversion of radiant energy. Stable and durable reflective coatings and backing materials are needed for solar-radiation receivers. Techniques of folding, releasing, inflating, and maintaining inflation of balloon-like collecting surfaces must be developed.

Materials for Engine and Vehicle Structures

Engine materials that operate at thousands of degrees during powered phases of flight may drop to nearly absolute zero during coasting phases; structural materials may vary through nearly as wide a range. Such diverse materials must be studied as metals, plastics, ceramics, cermets, and heterogeneous materials and coatings with properties tailored for use in extreme temperatures, both high and low, and in extreme temperature gradients. Materials for the external shell of the vehicle must also be resistant to erosion by micrometeoroids; the rates of erosion and penetration of representative metal and plastic structural elements subjected to micrometeoroid bombardment must be determined. After the micrometeoroid's mass- and energy-spectra have been established by IGY program results, laboratory methods of creating similar particles and of accelerating them must be developed, so that extensive ground-based research can be carried on.

Structures for Launching

Considerable knowledge of the problems of designing for launching has already been acquired from experience with ballistic missiles. The aerodynamic loads and aerodynamic heating of the vehicle are not severe, and this fact permits a light structure. On the other hand, the payload will commonly require protection from even these loads and heating. Jet-reaction controls impose bending loads on the vehicle; sloshing of propellant in the tanks aggravates these forces. The principal problems requiring study are thus payload packaging and the strength and rigidity of tank and structure.

Structures for Space Flight

Vehicles in space have small applied loads. There are no aerodynamic or gravitational forces, and vehicle acceleration will generally be only 0.1g or less. Although these factors permit light structures, there are additional problems in structural design, and these problems must be investigated to keep low the weight penalties they introduce: a manned vehicle containing a reactor can have low reactor-shield weight if the structure widely separates crew and reactor; the structure must resist vibratory forces from crew motion, power plant, and other machinery; solar radiation and heat from within the vehicle will introduce thermal distortions; it must be possible to launch the structure in pieces and assemble it in space; critical areas must be protected from damage by meteoroids, and the structure must accept some erosion and penetration by meteoroids; for vehicles using liquefied gases as propellant, an insulated, pressurized tank must be provided.

Materials and Structures for Re-entry Operations

The re-entering vehicle will be small compared with either the spacecraft or the launching vehicle. The only items requiring safe return to earth are men, valuable records, and specimens requiring inspection on earth. Thermal protection for re-entering vehicles is a problem area in which we have made notable progress. The expected extremes of the environments must be investigated, and the emphasis must shift from mere survival to optimum design. Techniques which must be studied more vigorously than at present include internal cooling, film cooling, transpiration cooling, ablation, and endothermic decomposition. Low-thermal-diffusivity materials with high heat of fusion or heat of decomposition, good mechanical strength, and low density must be sought for use in the latter two techniques. For the other techniques, structural constructions must be sought that allow effective cooling, that have low weight, high strength, and resiliency, and that can be fabricated simply and reliably.

Dynamics of Structures

Because most of the large structures in the flight vehicle are of extremely light construction, their dynamic behavior becomes of great importance. The natural vibrational modes and frequencies must be determined by analysis, model experiments, and full-scale experiments (the free mode of suspension must be simulated in full-scale system tests); methods of damping and of separating natural structural frequencies from any forcing frequencies of the system must be examined. The interactions among the vehicle structure, guidance system, power plant, and their controls must be studied first on a laboratory scale, with the aid of simulators, computers, and models; then in full-scale ground tests of the entire vehicle; and finally in flight. Control and stability derivatives and criteria, as well as methods of analysis and operation, must be established as guides for future design.

Launch, Rendezvous, Re-entry, Recovery, and Flight Simulation

LAUNCHING

The launching phase of flight is characterized by a need for large, high-impulse rockets which are reliable and controllable, and by the need for precision guidance equipment. The relatively high probability of accident with current liquid-propellant rocket systems cannot be tolerated either from a safety, cost, or logistics point of view.

Ground test. Many of the problems of boosting to orbit and beyond do not require flight facilities. For example, rocket propellant systems of high impulse and reliability are being developed in static test stands. Similarly, lightweight structures and guidance components are largely developed in ground tests. Aerodynamic problems such as loads during yawed flight and during separation of stages, high-altitude separation of the external flow by the underexpanded jet, and heating of the base region by the jet are under study with scale models in NACA wind tunnels. In addition, wind-tunnel tests are underway to establish promising configurations for turbojet and ramjet boosters, relatively recent concepts in propulsion technology requiring intensive evaluation of such problems as variable-geometry requirements of the induction system and protection against aerodynamic heating. All of these research areas must be greatly expanded if satisfactory solutions are to be reached at an early date.

Flight test. Some boost problems require information best obtained during actual launchings. The problems include: (a) the dynamic interactions of propulsive thrust, inertial forces, and air loads through flexible structures and fluid systems; (b) factors affecting the performance of guidance components of various stages in the presence of boost dynamics; (c) development of improved ground monitoring, flight path computing, and corrective techniques necessary to the precise establishment of initial orbits; (d) booster separation and thrust cutoff; (e) flight development of ramjet boosters with components too large for full-scale free-jet testing; and (f) flight checks on jet interference effects and corrective measures currently under study.

RENDEZVOUS

One of the difficult problems which must be solved is that of achieving physical contact between two satellites. This operation must be repeated many times in the course of assembling and maintaining space stations or vehicles. Successful mastery of this problem eliminates the need for gigantic boosters to put the complete system into orbit in one launching; these boosters would be extremely large and would risk the entire operation on one firing.

Flight paths. Special analyses pertaining to the establishment of flight rendezvous must be undertaken. Calculation of orbits and orbit motions around the oblate earth is a special segment of the Space Mechanics research described elsewhere. Many calculations must be made to find the simplest paths for effecting rendezvous from the launching site or from other sites in use.

The opportunity for putting a second satellite into exactly side-by-side flight with a preceding satellite from the same launching site and with essentially the same boost flight plan is infrequent; the probability of rendezvous increases as the orbits approach the equatorial orbit.

The analyses must determine not only the best times for rendezvous but the additional energy required when perfect rendezvous are not possible or fail because of control deviations.

The additional energy required for bringing imperfect orbits together is a function not only of the amount of correction required but of the time allotted to achieve the correction. Minimum-energy closing flight paths as well as those which compromise energy for the sake of time must be studied. Correction to both orbits may prove desirable.

Propulsion. The flight-path studies are influenced by the type of propulsion system available. The rendezvous techniques with a few large or with many small chemical rockets will be different from each other as well as from the methods of applying continuous ion- or plasma-jet thrust. Studies of the type described will help establish the type of orbit-control propulsion systems to be emphasized for various missions. Even the relatively simple motions of men moving in the space surrounding spaceships must be studied to determine the best means of locomotion.

When ion- or plasma-propulsion systems utilize nuclear energy and shadow shielding of their reactors, the most desirable closure paths may be those that do not expose one vehicle to the radiation field of the other.

When chemical attitude-control rockets are used, an additional problem is to avoid heating of surfaces adjacent to the jets.

Guidance. Satellite tracking and instructions from the ground will probably direct the initial closures. Final closure will inevitably be guided by one or both of the satellites using their own relative tracking equipment and their own computers. Research leading to the development of suitable lightweight equipment is required.

REENTRY

One of the hazardous parts of flight in manned spacecraft is re-entry into the atmosphere. During this phase of flight the occupant is threatened by both deceleration loads and aerodynamic heating. In addition, he must preferably alight at a relatively small preselected site at a relatively low, preselected velocity.

The NACA is already engaged in studies of the re-entry problem. Optimum re-entry flight paths to minimize heating and acceleration forces due to aerodynamic drag are being sought. These optimum paths are a function of the density of the configuration, its shape and the extent to which variable geometry is utilized, its ability to cool or dissipate heat, and its velocity and angle of entry. Not only must optimum paths be established but the consequence of error in control must be evaluated.

Aerodynamic heating. Fundamental research is underway on boundary-layer development, transition, and heat transfer. At the high reentry temperatures, molecular vibration, dissociation and recombination, and ionization occur in appreciable amounts. Application of magnetic fields may serve to utilize these effects to advantage. Preliminary studies have already provided important insight into the problem, but the work must be extended to apply more nearly to configurations suitable for manned reentry rather than to ballistic nose cones.

Cooling. The consequences of aerodynamic heating may be combated with various cooling techniques involving radiation, heat capacity, film cooling, free and forced convection, and ablation. Boundary-layer theories are being developed which include the effects of such complications as the addition of fluid to the boundary layer, such as occurs in the case of an ablation surface or of film injection. Many empirical data are required in the area, however.

Development of large-scale facilities to generate simultaneously the true pressure, velocity, and temperature environment, and the gaseous constituents, has so far proven very difficult. Small-scale facilities exist, however, and continuing research is necessary to improve not only the facilities but interpretation of the data from them.

Loads. The aerodynamic loads during reentry not only determine the safety and comfort of the occupant but the heat loads as well. Small-scale studies are underway to provide experimental checks on the validity of current theories for calculating these loads throughout the free-molecule-, slip-, and continuum-flow regimes.

Configurations under study include capsule types suitable for ballistic type deceleration and parachute landing, and winged glide vehicles which can be maneuvered in the atmosphere and landed like an aircraft. Accurate knowledge of the lift and drag is required to fly a preselected flight path. The stability and controllability of these craft during reentry must be established to insure safe flight.

Guidance. Errors in flight path can result not only from inadequate theories or data to use in trajectory calculations but also from inadequate guidance and control. Studies must be conducted to establish the optimum manner of applying decelerating forces to the reentry vehicle in order to minimize the energy required and the chance for error. The effects of flight-path error on loads, heating, and motions must be determined.

Flight. Since many of the problems associated with reentry can be studied only by actual flight, it is important to enlarge the program of unmanned flight testing of the better configurations arrived at from laboratory research. Test vehicles would be heavily instrumented to determine motions, loads, temperatures, and guidance parameters. Having ascertained that the vehicles can descend safely along a controlled and predetermined flight path, the piloted phase would begin, with successively more difficult reentries being attempted. The X-15 flight test program will constitute an important initial step in the reentry problem.

RECOVERY

After the space vehicle has slowed to moderate supersonic speeds where deceleration loads and heating are no longer a problem, it must still be flown through the transonic- and subsonic-speed ranges to a safe landing. The capsule-type vehicle will simply be decelerated by aerodynamic drag to velocities at which a parachute may be deployed for landing purposes. In event of a water landing, present techniques for flotation, location, and pickup must be refined.

The winged reentry vehicles must be studied in existing wind tunnels to determine their flight characteristics at supersonic, transonic, and subsonic speeds, including landing speeds. The optimum configurations for reentry probably must be modified to insure safe flight throughout the low-speed range; these modifications must be determined concurrently with the high-speed experiments in order to avoid wasted effort.

FLIGHT SIMULATION

A major question in the control and guidance of space flight and the associated atmospheric exit and entry, is the influence of the vehicle motions on the performance of the human or automatic controller. In many instances, these vehicle motions will differ importantly from those experienced to date in conventional atmospheric flight. For instance, a space or satellite flight will involve a relatively prolonged longitudinal acceleration or deceleration in the exit and reentry. How will the human react to this and how will his ability to perform a precise control task be impaired? What effect will this have on the drift rate of an inertial guidance platform, or the accuracy of an angular accelerometer? Secondly, the dynamics of the vehicle will be markedly different from those with which we have current experience; reduced or nonexistent damping will result in highly oscillatory or divergent pitching oscillations which in turn will have their influence on the human or automatic controller, Finally, the controls will in some cases be of the reaction rather than the conventional displacement type, and will probably have strong cross-coupling effects.

All these factors emphasize the fact that past flight experience will not be an adequate guide to the required performance of spacecraft flight controls; furthermore, the desired experience cannot be built up in actual flight, since failure will be catastrophic. Thus, there is an evident need for studying the influence of vehicle motions on a human or automatic controller. This need may be met by using motion simulators tied in with an analog computer, that will subject the human and automatic components to the linear and angular accelerations of a flight mission as produced by the "controller" inputs or by outside disturbances, and by computing trajectories resulting from these motions with a digital computer. An insight is needed into the interrelations of controller characteristics, vehicle dynamics, and resulting flight trajectory.

Measurements, Communication, and Guidance

NAVIGATION, GUIDANCE, AND CONTROL

Flight through space will require communication, navigation, and guidance systems of far greater range and accuracy than heretofore required for flight through the atmosphere. Equipment now available or in advanced development stages is suitable for guiding manned satellites into and out of orbit; the accuracies presently available, however, are not sufficient to insure satisfactory rendezvous of earth satellites, for precise re-entry guidance of satellites, or for lunar or planetary flights. To design satisfactory systems, significant advances must be made in several problem areas:

(1) Navigational instruments for reference to inertially or electromagnetically stabilized platforms, or to the earth's magnetic field, or to radio signals from the earth, or to the positions of earth, moon, and stars, in order to provide precise knowledge of vehicle orientation, position, and velocity; and instruments and techniques for combined use of several aids and of smooth transfer of emphasis from one navigational aid to another (particularly in landings) with full adjustment of navigational programs to the capabilities of automatic and human controls;

(2) Techniques and apparatus for tracking from the ground, computing deviations from a prescheduled program, and relaying corrective signals to the vehicle;

(3) Mechanical, electrical, and hydraulic systems for converting guidance intelligence into control operations;

(4) Aerodynamic and jet-reaction control systems for boosters, and jet-reaction control systems for spacecraft;

(5) Integration of power plant control with the guidance of the entire vehicle, incorporating all vehicle stability parameters;

(6) Scheduling of dead weight disposal, of separation, and of transfer from one method of guidance control to another;

(7) Control of vehicle direction, velocity, and acceleration, particularly in order to affect rendezvous; and matching all requirements for judgment to the faculties of the "pilot" (whether he is in the vehicle or on the ground), by extensive use of pilot-training simulators that include psychophysical and physiological effects;

(8)Techniques for linking various navigation and guidance components into complete systems.

Unique design problems arise from the need to minimize mass and volume of vehicle-carried instrumentation, because of the premium imposed by high ratios of take-off weight to payload weight. The same requirements for extreme lightness result in structures that are subject to considerable flexibility, particularly for boosters, high-performance gliding re-entry satellites, permanent space stations, and interplanetary spacecraft. The structural flexibility will result in interactions among the structure, the guidance system, and the propulsion-system controls that must be studied first in the laboratory, using analog simulators; next, on complete ground-based systems; and, finally, in flight.

COMMUNICATION AND DATA TRANSMISSION

Research must be performed on techniques and apparatus for transmission of information to the ground for high-speed data processing, for transmission of corrective guidance signals from the ground to an unmanned vehicle, and for communications between the ground and a manned vehicle as well as between manned vehicles. Among techniques that must be investigated are simultaneous use of optical and radio-frequency trackers, high-speed electronic computers, and ultra-stable clocks to perform automatic computations of speed and direction; and automatic phasing of relay stations around the earth to maintain continuous communications with an orbiting vehicle. Basic laboratory research, by use of electro-mechanical simulators, must be supplemented by field measurements. Optimum frequency bands, and modulation and commutation methods, must be determined that will yield highest signal-to-noise ratio and highest information content.

MEASUREMENT AND OBSERVATION TECHNIQUES

Each phase of the research program requires unusual techniques and apparatus of measurement and observation. Other measurements are the actual goals of flight in space. The research program must therefore treat measurements both as intermediate steps and as final goals.

The program emphasizes that work which can not efficiently be performed elsewhere for reasons of urgency, economy, expense or uniqueness of required facilities, or close interrelation with other research facilities of the organization. This implies that great reliance is placed on fundamental instrument research performed by other agencies directly concerned with physics, biology, and medicine, and on collaboration with these agencies; that maximum possible use is to be made of available commercial instruments and industrial skills; and that the Laboratory's own research is concerned principally with advanced instruments whose commercial counterpart does not exist, and with adaptation and application of existing instruments to space flight research.

Some areas in which research, development, or application is required are the apparatus and techniques for:

(a) monitoring of static and dynamic pressures, temperatures, and flow rates of highly reactive or erosive propellants used in chemical rockets;

(b) measurement and control of flow rates, flow-rate ratios, pressures, heat-transfer rates, and thrust direction in chemical and nuclear rockets; systems tests using electromechanical simulation of chamber, injector, propellant-system, or reactor characteristics in preliminary laboratory tests; and final field tests of the actual system;

(c) measurement and control of local fuel-element and coolant temperatures, and of local reactivities, in nuclear power plants; and monitoring of the chemical and physical condition of reactor- and heat-exchanger materials and structures;

(d) control and guidance of remotely-operated devices that must replace human hands and senses in the conduct of hazardous ground tests and in the operation of unmanned flight vehicles;

(e) measurement of such parameters of ion and plasma jets as jet thrust, jet velocity, ionization efficiency, and potential and charge distributions;

(f) measurement of the high temperatures, velocities, and heat-transfer rates associated with the launch and re-entry phases of flight, both in actual flight and in laboratory simulation of flight (as in wind tunnels, shock tubes, and ballistic ranges);flight (as in wind tunnels, shock tubes, and ballistic ranges);

(g) observation of the profiles of fluid temperature, pressure, and velocity in pumps, turbines, and heat-exchanger passages, and at the surfaces of nose cones, nozzles, guide vanes, and vehicle shells;

(h) monitoring the kinematic behavior and the internal condition of the vehicle—the structural temperatures, deflections, and stresses; the condition of the power plant, of the navigational and guidance devices, and of the instrumentation; and the physiological condition of the occupants;

(i) simulation of acceleration, temperature, and pressure environments for testing and for research;

(j) measurement of upper-atmosphere properties by adaptation and installation of nuclear-, optical-, radio-, and mass-spectrometers, magnetometers, electrometers, and thermometers; since the energy density in space is so low, unusually high sensitivity is required to ensure that the instruments are influenced primarily by the atmosphere under study rather than by the vehicle on which they are mounted;

(k) automatized collection, transmission, and analysis of data;

(l) engineering, evaluation, and field testing of complete instrument systems.

Space Mechanics

Space mechanics refers herein to the study of the motion of vehicles engaged in flight through space. The most analogous area in conventional aircraft technology is that of mission studies. The missions to be studied are those of earth satellites, and flight to our moon, Mars, Venus, and other planets of the solar system. In only the first four might the vehicles be manned. The unmanned flights to the outermost planets might not return within the lifetime of the launcher but nevertheless would be desirable scientific investments. The mission studies preceding even the short flights will of necessity dwarf the efforts which are standard in aircraft practice.

Calculation of Flight Paths

It is first necessary to apply high-speed digital computers to the study of flight paths through two-, three-, and multi-gravitational force fields. The effects of continuous or intermittent propulsive thrust of arbitrary direction and magnitude must be incorporated into these analyses. In addition, the effects of atmospheric drag must be calculated if the flight paths dip into the dissimilar atmosphere of the various planets. This work, already underway, must be greatly expanded.

Measured flight paths with the first, relatively simple vehicles will help determine the accuracy of these calculations and to refine procedures. The first earth satellites are already serving this function; they must be followed soon with lunar and planetary probes which may carry only electronic equipment to facilitate tracking.

Navigational Computations

Computation of the vehicle's location relative to the sun and the planets at various points of the flight path must also be undertaken, using distant stars as references. These calculations will not only determine the design of navigational equipment but may influence the choice of flight path. The performance of inertial-guidance components along the flight path must be calculated for similar reasons.

Pertinent to the general navigational problem is a study of the effect of errors in thrust application, introduced by such factors as misalinement and inaccuracies in thrust cut-off. The consequences of errors in navigation must also be evaluated.

Subsystem Optimization

One vital function of mission analysis is the parametric study of spacecraft systems and subsystems. Even without optimization of the complete mission, insight may be gained into the effects of variations in many propulsion system parameters such as weight and impulse, or even operating temperatures and component efficiencies. Configuration parameters affecting structural weight and payload may also be evaluated on "missions" in order to provide guidance in the selection of configurations for ground and flight tests.

Mission Studies

Each mission requires the choice of flight plan and vehicle configuration; these are not independent. Among the gross variables entering into the flight plan are date and time of launch; power-application schedule, including magnitude, direction, and duration of thrust; flight path; and total duration of flight.

The most important configuration parameters from a performance viewpoint are related to the type of power plant used (for example, chemical rocket, nuclear rocket, ion or plasma jet). With each engine type the parameters of greatest significance are impulse and thrust-to-weight ratio.

A basic aim of the missions studies is to find the combination of flight plan and vehicle system that will reduce flight time, increase payload-to-gross-weight ratio, or increase accuracy of navigation. Determining optimal combinations involves analysis of a multitude of flights. Such studies also reveal the relative importance of various research problems.

Space Environment

Space environment research includes the measurement of the properties of space pertinent to both manned and unmanned space flight; the provision of a safe environment for man for long periods of time; the solution of operational problems of final rendezvous and assembly of vehicles in orbit; the operational problems of navigation, operation, repair, and maintenance of spacecraft; and space exploration problems. Means for carrying out this research must include both experiments on the ground and experiments conducted in space. Such experimentation will involve close collaboration with other national scientific agencies expert in the areas of interest; in particular, fundamental scientific observations and research in space will be under direct cognizance of such agencies.

PHYSICAL MEASUREMENTS

So complex and expensive an operation as launching of a satellite-, lunar-, or interplanetary-vehicle is justified only when maximum use is made of the vehicle. This implies that wherever feasible, the vehicle should be used not merely to collect data about itself and about how to improve its launching, flight, and operation, but also to collect fundamental scientific data that will expand man's knowledge. Reciprocally, such data will assist in design of future vehicles and in planning their missions.

One such group of data involves those properties of the upper atmosphere and of outer space that affect flight and that influence terrestrial phenomena, such as weather and communication. Some of the physical, chemical, geophysical, meteorologic, and electric properties that must be measured are:

(a) the subatomic, ionic, atomic, and molecular composition and density of the atmosphere;

(b) the wavelength- and energy-distribution of cosmic-ray, ultraviolet, visible, infrared, and radio-frequency radiation;

(c) the integrated radiation and the albedos in broad bands of the spectrum;

(d) the distribution of gravitational, electric, and magnetic potentials around the earth and of their secular and random variations;

(e) the conductivity and transmissivity of the atmosphere for electromagnetic radiation;

(f) the cloud-cover distribution;

(g) the micro-meteoroid population density, speed, direction, and size; and the systematic and random distributions and distribution laws of these quantities.

The effect of some of these physical variables on the vehicles or its contents may in some instances be determined by appropriate ground simulation of upper-atmosphere conditions, but in other cases major flight research efforts are required, progressing successively through the stages of sounding rockets, unmanned spacecraft, and manned ones.

Much of the required information will be obtained by IGY-program observations, but these data will require collation and analysis. Continued experimentation and analysis will be necessary to extend, verify, and (sometimes) explain the IGY data.

BIOLOGICAL PROBLEMS

The biological problems of space flight stem from environmental factors such as nuclear and cosmic radiation, variable gravity, absence of an atmosphere, and alien planetary conditions. The effect of the space environment on nonhuman life forms such as plants and bacteria must be investigated for application to ecological systems and medical problems. The initial research must determine the magnitude of the presently known biological problems, and must endeavor to uncover new problems by experiment and observation.

Crew environment. The health and efficiency of man demand carefully controlled cabin conditions. An important research problem here is the development of mechanical, chemical, and biological means for sustaining the oxygen-carbon dioxide cycle. Development of compact, lightweight, reliable air conditioning equipment is also necessary.

Metabolism research. The reprocessing of water will be an extremely important function in long space missions. Methods and equipment for this function must be developed. Small, lightweight, and reliable ecological systems offer possibilities for continuous food and oxygen supplies on long missions; research in this area must be pursued. Adaptation and application of medical-research instruments, techniques, and apparatus to any particular flight mission will itself require applied research and engineering development. Similar application engineering will be required for such medical techniques as conditioning of the blood stream against radiation damage.

SPACE OPERATIONS RESEARCH

Final rendezvous and assembly of large satellites and spacecraft in orbit around the earth require research on techniques, methods, equipment, and tools. The various manual functions of the crew during space flight and in a satellite space station will require research because of the variable gravity conditions. Special mechanical aids and techniques may be necessary in the performance of navigation, control, operation, repair, and maintenance of spacecraft and auxiliary equipment. These space operations problems can be crudely simulated by submersion in a water tank; but determination of the physiological effects of weightlessness requires techniques that sufficiently prolong the period of approximately zero-g acceleration so that physiological steady-state conditions may be reached. Such techniques include very-high-speed parabolic-arc flight in a conventional airplane; free fall from high altitudes, in capsules; and flight in orbiting vehicles.

SECTION III

Proposed Facilities For Existing NACA Laboratories

Introduction

Implementation of the research program outlined in the preceding section requires a large and rapid expansion of the NACA staff, modification and extension of existing NACA facilities, and the acquisition of new research facilities. Experiments with large or hazardous systems for space vehicles will be conducted at a proposed new laboratory in a safe location. Other research which is specifically connected with these large or hazardous experiments will also be conducted at the new laboratory. The existing NACA laboratories will be modified and expanded to permit additional research in fundamental physics and chemistry, research on components, and small-scale testing of a relatively nonhazardous nature; by performing such work at the existing laboratories, large economies in time and money can be realized. Furthermore, many of the research areas represent a natural continuation of present NACA effort, and a nucleus of competent and trained personnel already exists.

Construction of these facilities should be started immediately and completed within a 5-year period.

Energy Sources And Propulsion Systems

Chemical Rocket Facility

The NACA has a highly skilled and trained staff of scientists and engineers in the field of chemical rocket propulsion. Considerable research has already been done on basic concepts and design principles for rocket components. In order to support a full-scale space program, the research effort on both liquid- and solid-propellant rockets for launching, sustained flight, and re-entry must be expanded. The existing rocket facility, principally designed for work with low-thrust engines, will be used, as in the past, for fundamental research. A number of larger test stands is needed to determine problem areas and to provide research rockets which will more nearly simulate the problems of full-scale equipment needed for advanced missiles and space vehicles.

The need for storable propellants of high specific impulse becomes increasingly important when landing and return flight is contemplated. The reliability and storability of solid propellants makes them attractive for long-duration voyages. A facility for an expanded research effort on storable propellants is thus proposed.

Specifically, the following items are required:

Storable Propellants Laboratory. Synthesis of storable, high-specific-impulse propellants will be studied. Chemistry laboratories for the study of advanced propellant compositions are included, as well as equipment for preparing and testing these propellants.

Rocket Dynamics Laboratory. Test stands for studying interactions among the various parts of a complete vehicle or of its propulsion components, under simulated flight conditions, are required.

Altitude Test Laboratory. A means of testing liquid- and solid-propellant rockets under simulated high-altitude conditions is required to study problems of cooling, nozzle behavior, and controls.

Sea-level liquid-propellant test stands. Small liquid-propellant test stands are required to study the combustion, stability, and cooling problems of high-energy liquid-propellant rockets.

Control and Instrument Center. A single, central control and instrument building will serve all of the rocket test stands. High-speed recording instruments will be used for studies of transients and for short-duration runs.

Additions to Lewis Hypersonic Missile Propulsion Facility. Additions to this facility are required for investigation of the chemical problems of dissociation and recombination as they occur in rocket nozzles and in boundary layers. Atoms, free radicals, and ions will be produced in shock tubes; the rates of dissociation, recombination, and relaxation will be studied together with the influence of these processes on nozzle performance, boundary layer characteristics, and cooling. A low-pressure flow system is required to study the chemical processes previously mentioned in an environment simulating that existing in rocket nozzles and on missile surfaces at high altitude. A modification of the Lewis 10- by 10-Foot Supersonic Tunnel is needed to extend chemical and aerodynamic studies to Mach 15 and simulated altitudes of 20 to 55 miles. Chemical reactions have been studied in this tunnel at Mach 3. The modification is designed to permit normal tunnel operation at other times.

Electrical Propulsion Facility

In this facility the basic concepts and principles governing the design of low-thrust, high-impulse space propulsion devices, such as ion and plasma jets, will be studied. Because ion-propulsion research requires large quantities of electric power, and because this power is readily available at the existing laboratories, research on other components of electrical propulsion systems is also planned.

A study of the application of thermonuclear energy to space-propulsion systems requires many of the same laboratory tools as needed in the investigation of ion propulsion; small-scale experiments on controlled fusion schemes are therefore contemplated.

The large electric power supplies and vacuum systems required for the development of ion-, plasma-, and thermonuclear-propulsion systems are also essential in other research areas related to the space-flight problem. For example, they can be used to produce an electric-arc-heated air jet which is needed for materials and instrument research.

The following items are needed:

Ion and Plasma Propulsion Laboratory. Small-, intermediate-, and large-scale ion and plasma generators and accelerators, ranging in power from 3 to 100 megawatts.

Thermonuclear Research Laboratory. Several small test stations with high-current electrical service, hard-vacuum facilities, and shielding.

Power-Unit Research Laboratory. Several laboratories for development of light-weight electrical generators and coils, and for study and development of auxiliary power supplies using nuclear or radioisotope energy.

Space Simulation Chamber. A large vacuum tank, capable of being evacuated to 10^{-6} mm Hg and equipped with a solar-radiation simulator, for solar propulsion studies, solar-electric power unit development, and solar radiation control studies, directed towards temperature control of spacecraft.

Electric-Arc Propulsion Laboratory. Investigations of electric-arc propulsion devices are planned. Associated problems, such as electrode consumption, nozzle heat transfer, and nozzle flow characteristics will be studied.

Building structure and utilities. Because the transmission of electric power in the quantities required is very costly, it is necessary that the test cells with large power requirements be grouped close to the power conversion equipment. None of the existing laboratory buildings can be modified to accomplish this; therefore a new building is required to house the Electrical Propulsion Facility.

Nuclear Propulsion Facility

Nuclear fission is the energy source for the two most promising space propulsion systems. It supplies the power for the generators of electrical-propulsion devices and the heat for nuclear rockets. A great concentration of research effort is therefore required on this use of nuclear energy. Research on nuclear energy sources must be closely coordinated with other spacecraft and advanced missile research in order to achieve the most effective integration of all the sciences involved in a complete space craft or advanced missile. The conceptual and preliminary phases of nuclear propulsion research can be carried out at existing laboratories augmented with some new facilities. The final stages of research on full-power reactors, complete spacecraft, and advanced propulsion systems will be undertaken at the new laboratory.

Expansion of an existing NACA laboratory is proposed to permit study of the fundamental concepts and principles of design of space propulsion systems, and also to provide for the creation of new methods that exploit the full potential of nuclear-fission energy. The items required are:

Critical-Assembly Laboratory. Critical assembly cells are provided for three types of experiment aimed at determining the nuclear behavior of reactors. Cold critical assemblies provide, at room temperature, data on neutron flux and power distributions, control characteristics, control rod effectiveness, critical mass, and other information necessary for the determination of transient and static characteristics of advanced reactor conceptions. Hot critical assemblies are provided to determine the same characteristics at temperatures existing in the actual proposed reactor. Hot dynamic critical assemblies are provided in addition, wherein full-scale coolant flow is supplied. These tests determine the effects of hydrodynamic phenomena, dynamic loads, and their actions on the neutron distribution and the control characteristics.

Reactor Components Research Laboratory. Space and equipment for reactor fuel-element research from initial small-scale testing to final test in the Plum Brook reactor. Supplies of hydrogen, helium, liquid metals, and boiling metals will be circulated through electrically-heated research fuel elements. Loops with circulating coolants of interest will be built and developed to test promising fuel elements in the Plum Brook reactor. A pool is provided for final underwater tests of the in-pile loop with the actual coolant flows, temperatures, and pressures to be obtained in the in-pile test.

Physics, Radioisotope, and Gaseous Reactor Laboratory. A water pool is provided for fundamental research on shielding, research on power from radioisotope decay, and for the study of radiation effects on bearings and lubricants. Laboratories for research in hydrodynamics, electromagnetic fields, heat transfer from partially ionized mixtures of uranium and hydrogen, instrumentation, and fundamental physics are supplied to study the problems of gaseous reactors.

Space chamber. A space chamber with a vacuum system is provided for testing radiator elements for nuclear-electric space power plants. The chamber is located near the Reactor Component Research Laboratory which supplies the high-temperature gases or the vaporized metal for the tests.

Materials and Structures

The differences between the environments to which advanced missile and space-flight airframes and power plants will be exposed, and previous aircraft and power-plant environments requires an appreciable increase in materials- and structures-research effort. New facilities required are:

Power-Plant Materials Research Laboratory. For basic research on the physics and chemistry of solids, and applied research leading to development of materials for

(a) containment of high-energy chemical propellants, (b) nuclear reactor fuel-elements and structural components, (c) heat exchangers, and (d) electrical propulsion devices.

Spacecraft Materials Laboratory. Advances in space-flight structures are critically dependent on advances in materials and materials fabrication. This laboratory is for research on such diverse materials as metals, plastics, ceramics, and cermets for structural use and on heterogeneous materials with properties tailored for insulation, heat absorption, and controlled expansion. The research results on materials will be integrated with parallel research on structures.

Power-Plant Structures Laboratory. This laboratory is for studies of (a) power-plant structures for both chemical and nuclear rockets and hypersonic air-breathing engines, (b) design and construction methods for large, lightweight propellant tanks for chemical and nuclear rockets, and for pressure vessels for nuclear-rocket reactors, and (c) cooling of surfaces exposed to very high heat fluxes.

Spacecraft Structural Components Laboratory. The extreme premium on structural lightness that is inherent in space flight will undoubtedly lead to unique, very-lightly-loaded structures having very thin shells. Research on components for such structures requires a laboratory which will include equipment for simulating much of the significant environment to be encountered by space structures. A considerable expansion in size and facilities of fabrication shops will be needed to support this research.

Temperature-Distribution-Control Laboratory. The problems of controlling the magnitude and distribution of heat loads in spacecraft structures are quite diverse—they cover a range from protection against re-entry heating to balancing and redistributing the human, equipment, and solar heat loads in a long-duration or permanent spacecraft. Because of the wide diversity of the problems and of the techniques to be used in solving them, a special laboratory is needed to study temperature-distribution-control systems. The equipment will include a large centrifuge, with heat source, for study of the problems of internally removing heat during re-entry. The large decelerations during re-entry greatly complicate the internal heat transfer due to free convection and surface boiling.

Structures and materials research tunnels. Tunnels are required for simulation of the environments of re-entry and flight at hypersonic speeds within the atmosphere. The tunnels will be adjacent to the Electrical Propulsion Facility in order to share the vacuum-pumping system and the electric-power supply. There will be a pebble-bed-heated tunnel providing temperature to 4000°F and velocities to Mach 7, and several arc tunnels providing various combinations of Mach numbers, temperatures from 10,000°F to 30,000°F, and Knudsen numbers ranging from the continuum region to the free molecule region.

In other facilities high-temperature gases will be produced by a cyanogen-oxygen burner and by a nitrous-oxide compressor to provide Mach-15 gas streams with temperatures from 5,000° to 10,000°F at stagnation pressures of 300 to 1000 atmospheres.

Diffuser for 9- by 6-Foot Thermal-Structures Tunnel. The existing 9x6-Foot Thermal-Structures Tunnel at Langley was designed for structural research on high-speed aircraft operating at altitudes up to about 70,000 feet. The addition of a diffuser to this tunnel will allow it to operate at effective altitudes over 100,000 feet for structural research on boosters and spacecraft during the launching and re-entry phases of flight.

Hypervelocity-Particle Laboratories. These will provide facilities for research on the impact of high-velocity particles with materials of typical vehicle and power-plant structures. Techniques for controlling size-, number-, and energy-distributions of solid and liquid pellets must be developed as the first step of this research.

Launch, Rendezvous, Re-entry, Recovery, and Flight Simulation

Launching, Re-entry, and Recovery

Aerodynamic problems of spacecraft are essentially confined to the boost, re-entry, and recovery phases of flight. A large effort in these research areas, directed toward a solution of ballistic and boost-glide missile problems, and toward satellite re-entry problems is being carried out at the existing NACA laboratories. However, considerably more work is required before manned flight into space and manned entry into an atmosphere are assured of success. The solution of the aerodynamic problems of spacecraft requires that several of the existing facilities be modified, and that a number of new facilities be added to the existing laboratories.

Specifically, the following items are required:

Atmosphere Entry Simulator. This facility will provide equipment necessary for the investigation of entry into planetary atmospheres by vehicles of any particular design flying an entry trajectory appropriate to that design. Vehicle motion, heating, and surface erosion will be investigated by using various simulating facilities, each having a supersonic nozzle that will duplicate the density distribution and composition appropriate to the particular atmosphere and trajectory under consideration; a hypervelocity gun will launch scaled models of the proposed vehicle upstream through the supersonic nozzle. This facility will provide a natural extension of present NACA research with ballistic-entry simulators and will cover the cases of gliding, grazing, and skipping satellite re-entries.

Hypersonic Free-Flight Facility. This facility will permit measurements or observations of aerodynamic forces and moments, flow-field geometry, heat transfer rates, and boundary-layer characteristics on scale models in free flight at velocities up to 35,000 feet per second. It consists of a shock-heated, short-duration, hypersonic wind tunnel in combination with a hypervelocity gun for launching models upstream through the hypersonic air stream.

Planetary-Atmosphere Wind Tunnel. This wind tunnel will provide information concerning forces, moments, and heat transfer rates that would be experienced by a space vehicle while flying in the atmosphere of neighboring planets. The supersonic wind tunnel is capable of operating with gas mixtures that duplicate planetary atmospheres. Auxiliary equipment includes compressors, evacuator, and gas-storage spheres.

Large-Scale Hypersonic Wind Tunnel. A large aerodynamic facility capable of operating at very high velocities with Reynolds numbers approaching those of full-scale re-entering vehicles is needed to study aerodynamic performance and heating problems during re-entry. This need will be filled by a 4-foot-diameter blowdown tunnel using 700-atmosphere stagnation pressure, and a 5000°F ceramic-pebble-bed heater. The Mach number range is 18 to 40 with helium and 12 to 18 with air or nitrogen.

Extension of Langley Hypersonic Facilities. Several of the Langley Laboratory hypersonic facilities require modernization on extension of capability in order to study the problems associated with manned entry into an atmosphere. Included in this category are: increased compressor and vacuum-pump capacity for the 20-inch helium tunnel, a 4-foot-diameter Mach-15 air jet of 5000°F stagnation temperature and 200-atmosphere stagnation pressure, a 2-foot-diameter hypersonic nozzle for the 16-inch free piston compressor, instrumentation and recording equipment for the 30-inch hypersonic tunnel and the 20-inch jet, and a heater for the 20-inch, Mach-8.5 facility.

Modification of Ames 8- by 7-Foot and Lewis 10- by 10-Foot Supersonic Tunnels. Second-throat modifications of these tunnels are required to increase their peak Mach numbers from 3.5 to about 6. This Mach number increase is required for the study, at the Lewis Laboratory, of launching problems such as base heating, nozzle performance, altitude starting, and stage-separation. The modification of the Ames facility will aid in large-scale investigations of the aerodynamics and thermodynamics of re-entry.

Hazards Laboratory. The dangers from fires, explosion, toxic fumes, and radiation are very great, particularly during the launching of manned satellites. Research on the prevention of and protection from such disasters requires concrete pads and bunkers, ventilated buildings, instruments, and devices to simulate certain critical loads and temperatures.

Flight Research

During the interim period before a final flight station is selected, constructed, and manned, significant progress can and must be made in both the manned- and unmanned-flight phases of space research. In order to accomplish this, the facilities at the existing NACA flight-research stations must be extended in range and capability.

Extension of Wallops Island capabilities will include increasing the range of telemeter-, radar-, and optical-tracking systems; providing a downrange remote radar and instrument station, a ship-borne downrange station, and launching, handling, guidance, and control equipment; and expanding the Langley and Wallops support facilities.

Extension of Edwards High Speed Flight Station facilities will include:

(1) Precision Radar and Telemetering Range Extension:—The existing range consists of three linked stations placed to handle the basic X-15 flight profile. This profile will be extended by changes in the propulsion system and addition of boosters. In addition, more advanced vehicles will be operated. Extensions of the existing range and of magnetic-tape data-processing equipment are required to handle these programs.

(2) Navigational Research Equipment:—It will be necessary to provide an adequate navigational system, for use by the pilot, that is consistent with the extremely high speeds and relatively short flight times involved in space and space-equivalent flight. Research on both equipment and techniques required in this problem area can be accomplished using the X-15 test vehicle. Some of the equipment required for such research includes an airborne navigational stable platform and necessary ground support equipment.

(3) Elevated-Temperature Structural-Calibration Facility:—In flight studies of structural problems, it is necessary to measure structural temperatures and stresses. To interpret the results of structural-temperature and structural-stress measurements, it is necessary first to calibrate the instrumentation, as installed in the test vehicle, to determine effects of temperature and loading. A facility large enough to handle a full-scale X-15 wing panel is required.

(4) Flight-Guidance Training Facility:—The increasing complexity of problems encountered in flight research at high speeds has led to the use of analog-computer simulation as an essential preliminary to the flight test in order to delineate problems, avoid hazardous conditions, and serve as a training device for the pilot. A facility such as this will be needed for the X-15 and for future spacecraft.

(5) Recovery Research Facility:—One of the problems of manned space flight is terminal guidance to return base. This problem can be studied in flight with the X-15 airplane. It will be necessary, however, to augment the existing precision radar range with an acquisition radar.

(6) Expansion of existing laboratory building:—Additional building space will be required to house new data-reduction and analog- and digital-computer equipment, enlarged instrument and radar laboratories and shops, and the enlarged research staff required to man facilities described above. This space is best obtained by enlargement of the present building.

Flight Simulation

The control and guidance of space flight and of atmospheric exit and entry is influenced to a large extent by the effects of vehicle motions on the performance of human and automatic controllers. Ground-based simulators are required for studying the interrelations of controller characteristics, spacecraft dynamics, and the resulting flight trajectory. This area of research is a logical extension of NACA work now in progress, so that the design and operation of new equipment will lean heavily on the experience already gained in operation of existing simulators.

Flight control equipment. The facilities described here will enable simulation of the control problems (both human and automatic) of space flight and of atmospheric exit and re-entry. Part of the equipment consists of (a) a six-degree-of-freedom motion simulator for imposing linear and angular accelerations on human subjects; (b) a whirling arm with a three-degree-of-freedom flight table for imposing motion inputs on automatic-control and guidance components; and (c) analog and digital computers to convert control actions of human and automatic operators into flight-path motions and trajectories and to command the drive system to produce accelerations in response to the control signals.

Measurements, Communications, and Guidance

New and improved instruments and techniques will be required not only to aid in navigation and in control of orbits, but also to provide measurements required in laboratory research. The following facilities are needed:

Instrument Research Facilities. Expansion of current work is required to develop the techniques and apparatus for measuring flight- and environment-variables, and, even more urgently, for making measurements in current research at hypersonic speeds, high temperatures, and low pressures.

Space Navigation Systems Laboratory. Obtaining the extreme navigational and guidance accuracy required for many phases of space flight depends strongly on having adequate reference instruments. Research on systems for space-flight-path selection and navigation requires a laboratory for research in analog information transfer, optical and electronic measurement, optical- and electronic-system coupling and simulation, and servo-, gyro-, and generator-performance.

Space Mechanics

Additional computing, data-collecting, and data-processing facilities are required for performing the intricate computations associated with selection of orbits and flight paths for space vehicles. Characteristics of propellants, propulsion systems, and vehicle structure must be considered. Human factors, guidance accuracies, and the limitations of communication systems enter into the analysis.

Space Environment

A number of research problems in the area of space environment must be studied by ground simulation before there is any actual flight testing. Typical of the problems are the aerodynamic and thermodynamic phenomena that occur in the slip-flow and free-molecule-flow regimes with ionized, dissociated, non-equilibrium gases. The NACA has done research in these fields by using such techniques as hypervelocity guns, shock tubes, and electric-arc-heated tunnels. This effort must be expanded; hence additional research facilities to extend our present capabilities are required.

Magnetogasdynamics Laboratories are required, wherein ionized gases and plasmas will be used to study magnetogasdynamic effects that occur in flight through space and in planetary atmospheres. Studies will be made of the effects of magnetic fields on gas flow and of the effects of this gas flow on boundary layers, heat transfer, and deceleration. This research will also aid studies of communication and tracking.

SECTION IV

PROPOSED FACILITIES FOR A NEW NACA LABORATORY

INTRODUCTION

A new NACA laboratory is necessary to provide the extensive facilities . . . for flight research and for research on large-scale components and complete spacecraft systems; these facilities also provide for necessary preflight tests of full-scale equipment. Some of the required ground facilities are of such a hazardous nature that none of the existing NACA laboratory sites provides adequate safety.

Sufficient supporting facilities are included to make the new laboratory self-sufficient, with both the facilities and the atmosphere for a well-balanced, integrated research effort.

ENERGY SOURCES AND PROPULSION SYSTEMS

Chemical-Rocket Research Facilities

The chemical-rocket research must include both use of high-energy propellants and scaling up of efficient, small-scale rocket designs to sizes suitable for launching. The necessary background for design of large rockets will be provided by preliminary research on small rockets. Both liquid and solid propellants will be studied. Complete, full-scale vehicles, that include the rocket motors, tanks, controls, turbines, and pumps, will be tested for the full duration of thrust production.

The chemical rocket research facilities . . . must be located in an isolated area with about 25-mile exclusion distance. In the prevailing downwind direction, an even larger exclusion distance should be provided, if possible, for dissipation of toxic rocket exhaust gases. The site must be large enough to allow one or two miles between large test stands, and several thousand feet between small test stands.

Large-scale chemical-rocket facilities. Each of several vertical test stands will be capable of testing a complete vehicle and its propulsion system in either single- or multi-stage versions. Both liquid- and solid-propellant motors will be tested. Supporting facilities for each stand are a water supply for cooling the jet and the flame deflector; an expendable building for supplies, tools, operating equipment, and vehicle assembly; an explosion-proof, concrete instrument vault at the test stand; and a remotely located control and instrument room. These stands will vary in their thrust capacity from 1,000,000 to 250,000 pounds. Some of these stands will use the turbopump propellant-feed system of the final vehicle; others will have a pressurized propellant system for testing the thrust chamber alone. All of these stands will exhaust directly to the atmosphere. . . . One of these stands will be equipped with an ejector for simulating altitude operation of the rocket with an exit pressure of 0.1 atmosphere. Another stand will be for studying vehicle systems under dynamic conditions. . . . This stand will incorporate a "soft mounting" in order to simulate the airborne condition of the vehicle. Vibrators will dynamically excite the vehicle while it is suspended in the soft mounting. Later modifications of this stand will allow "tethered flight" for even more realistic dynamic studies.

Small-scale chemical-rocket facilities. Small-scale rocket test cells . . . will be built for studies of gas generators, liquid-propellant injectors, thrust chambers, flow-control systems, and exhaust nozzles. They will have a maximum capacity of 20,000 pounds thrust. The cells will be designed for operation with fluorine and hydrogen, although other propellants, including solids, may also be used. Additional cells will be in a remote area for tests with ozone. All will be equipped with ejector systems for research at simulated high-altitude conditions.

Fuel-pump research facility. This building. . . . is for testing full-scale pumps for hydrogen, ammonia, hydrazine, and other fuels; reduced-scale hydrogen pumps for the nuclear rocket may also be tested here. Liquid hydrogen will be pumped directly from a low-pressure tank car into a high-pressure tank car. Gas turbines, operating with liquid-propellant gas generators, will be used to drive the pump rigs. One cell will be capable of testing turbopump units to study pump-turbine matching problems. A common control and instrument room will be located some distance from the cells.

Oxidant-pump research facility. Test cells of this building . . . each contain a pump stand, a gas turbine, a liquid-propellant hot-gas generator with its associated plumbing, a pump supply tank and the necessary piping. These cells will be devoted primarily to studies of fluorine pumps, but other oxidants may be investigated as the need arises. One cell will be capable of testing turbopump units for studies of pump-turbine matching problems. Fluorine will be recirculated from the pump outlet, through a liquid-nitrogen heat exchanger, and back to the supply tank. The pump will be housed in a small, metal-lined vault. A single control and instrument room will be located some distance from the cells.

Turbine and gas-generator research facility. In this building . . . gas generators using high-energy propellants will be studied under both sea-level and high-altitude conditions. Turbine studies will include evaluation of experimental turbines and fundamental aerodynamic design studies of high-work-capacity turbines. Turbines for nuclear rockets, using hot, gaseous hydrogen as the working fluid, will also be studied. A suitable power-absorption device, such as a water brake, will be provided.

Flow-metering building. This building contains three separated test cells, for flow studies with fuels, oxidants, and water, respectively. The facility will be used for routine calibration of flow metering and control equipment used in rocket tests, and for development of improved metering and flow-control equipment. Each cell will be provided with a supply tank and a receiver tank. The supply tank will be pressurized with high-pressure gas.

Operations and data-reduction building. This building will contain offices for research engineers and supporting professional staff, and for data-reduction equipment and its required operating personnel.

Chemistry laboratory. This laboratory will supply routine chemical analyses of propellants, pressurizing gases, and other materials for the Chemical-Rocket Research Facilities. In addition, special chemical analyses and studies of special analysis techniques required in rocket research programs will be conducted here.

Propellant-supply and -handling facilities. Because the location of the proposed laboratory, as dictated by safety considerations, may be remote from commercial sources of cryogenic fluids needed for rocket research, facilities are provided for their manufacture on the site. The facilities include a combination liquid-oxygen—liquid-nitrogen production plant, a fluorine generation plant, a liquid-ozone generator, and a hydrogen production and liquefaction plant.

Railroad tank cars and road trailers will be used both for storing and for transporting cryogenic fluids. A small number of stationary tanks for storable materials such as ammonia and hydrocarbons will be provided, Tube tank cars, roadable tube trailers, and compressors will be provided for handling gaseous hydrogen, helium, and nitrogen.

Nuclear-Rocket Research Facilities

Nuclear rocket research will be carried out on two different systems: high-thrust rockets for ground-to-orbit missions, and low-thrust rockets for missions in space. The facilities for small- and intermediate-scale experiments on low-thrust nuclear rockets to be carried out at existing sites are described in Section III. The facilities for small- and intermediate-scale experiments on high-thrust nuclear rockets, and the large-scale test facilities for both the low- and high-thrust systems, are located at the new site.

High-power-density test reactor. This . . . reactor will be for in-pile testing of single fuel elements in closed-loop experiments. Use of such a reactor will permit studying rocket elements at the design level of power density while consuming less time and less money than would a comparable test in a complete reactor for a rocket. A test reactor providing neutron flux adequate for testing rocket fuel elements requires a considerable extension of current reactor technology. For this reason, the hazards of its use may require a separate, remote site.

For such a test reactor, both neutron flux and power density must be increased about 20 times the magnitudes produced by the low-pressure, water-cooled, research reactor common today. Preliminary calculations indicate that three different types of reactor might be developed to meet the requirements: a supercritical-pressure, water-cooled reactor; a helium-cooled reactor; or a liquid-metal-cooled reactor. With each reactor system the ultimate potential would have to be approached in order to realize the performance required. Further study is required to determine which of the three systems would be best.

A preliminary design of a helium-cooled reactor is presented . . . in order to give some idea of what the test reactor might be like. Thermal-neutron fluxes on the order of 10^{16} neutrons per square centimeter per second are needed in the test holes. Helium would be circulated at high pressure and be heated in the core by molybdenum fuel elements. Water-cooled heat exchangers remove heat from the helium.

A test hole about 6 inches in diameter would be provided in a central island of beryllium for insertion of experimental rocket fuel elements. The discharge from the fuel element would be cooled, filtered, stored, and released to the atmosphere when at a safe level of activity.

A hot laboratory is required for detailed examination of irradiated specimens.

High-thrust nuclear-rocket systems facility. Use of large bodies of water is planned for the static testing of nuclear rockets. Obtaining the desired exclusion radius is facilitated by this approach and prolonged contamination of the test site is eliminated.

The test site will contain an underwater platform that is erected in relatively shallow water, like that on the continental shelf or adjacent to an unoccupied island or atoll. The top of the platform will be approximately 20 feet below the surface of the water in order to minimize neutron activation of the platform and to shield workers above the water from any radioactivity of the platform that might remain from a previous firing. In order to utilize the underwater platform for either static testing or launching, an erection barge, a fuel barge, and one or two tugboats are required.

The proposed method of static-test operation is as follows . . .: The erection barge is maneuvered to place the static-test superstructure onto the underwater platform, with the nuclear rocket engine supported out of the water and with its jet directed upward. The fuel barge is positioned and, after the fuel and control lines have been connected to the engine, is submerged onto its supporting platform. Pumps on the fuel barge supply fuel at any desired pressure to the turbopump. The erection barge is then removed to a safe distance, and the engine is fired remotely.

After shutdown, fuel is pumped through the reactor at a reduced rate and discharged to the atmosphere. When the afterheat decays sufficiently to be handled by a heat exchanger on the fuel barge, a cap is used to close the nozzle exit, and the hydrogen coolant is then recirculated. A mechanism on the fuel barge then removes the rocket engine from the test superstructure and submerges it in the water. The fuel barge is refloated and towed to the engine disassembly area, the rocket engine remaining submerged all the time.

In addition to the nuclear rocket engine itself, the steel superstucture is made radioactive by the firing. This superstructure is hoisted off the platform and sunk in nearby water.

Low-thrust nuclear-rocket systems facility. In this facility . . ., vacuum-pump capacity will be installed to permit testing of nuclear rockets with thrust up to 2500 pounds and chamber pressure as low as 2.4 psia. The exhaust gases from the rocket will be cooled, filtered, compressed, and stored. When the radioactivity in the stored gases is sufficiently low, these gases will be discharged through a stack.

Supporting facilities required are a critical assembly building for conducting critical experiments for the high-thrust nuclear rocket; a rocket-assembly and pretest building; a disassembly and hot-lab facility . . .; and a general laboratory building for small-scale, out-of-pile research.

Nuclear-Electric Propulsion Systems Facilities

This facility . . . will provide for operation of assemblies of . . . various full-scale spacecraft components to determine component interactions. Research on scaling techniques will permit prediction of performance of full-scale components from tests of smaller-scale components. Endurance and reliability will also be determined as a necessary step preceding flight. Because of the potential hazards from failure of nuclear reactors, this station will be located about 5 miles from the adjacent facilities, and a distance of one mile will be provided between the various facilities in the station.

Low-power-reactor research facility. Nuclear reactors will be assembled and tested here at low power (100 to 1000 watts) to obtain data on reactor criticality and neutron-flux distribution.

Small-power-plant systems facility. This facility . . . will be used for research with the small thermomechanical electric power plants that will be utilized in early spacecraft. For reasons of safety, the power plant components will be contained in a 20-foot-diameter, 60-foot-long tank; this tank can be evacuated to 0.02 atmosphere to approximate space environment. The complete power plant, except for the radiator, can be studied in this vacuum tank; thus, the tank will contain a reactor, complete shield (not the shadow shield planned for the flight model), heat exchanger, evaporator, turbine, generator, and pumps. In place of the large spacecraft radiator, heat exchangers will reject waste heat to cooling water. Shielding and cooling of the tank will be provided by immersing the tank in a 30-foot-deep water basin.

Large-power-plant systems facility. This facility . . . will permit simultaneous operation of all components of large spacecraft power plants. A 40-foot-diameter, 120-foot-long vacuum tank will contain all the power plant components except the radiator. The hot working fluid leaving the turbine can be fed either to heat exchangers which will reject waste heat to cooling water, or it can be fed to a spacecraft radiator installed in a 120-foot-diameter, 320-foot-high tank. This tank will be cooled by water sprays and will be evacuated by mechanical exhausters to 0.02 atmosphere to reduce windage forces on the rotating radiator, to avoid oxidation problems, and to reduce convective heat transfer.

Hot laboratory facility. This facility . . . will provide four separate hot disassembly and laboratory areas. Its central location will permit its use for all three reactor test facilities.

Full-scale ion- and plasma-jet systems facility. In this facility, several large vacuum-jacketed tanks, on the order of 50 feet in diameter and 50 to 120 feet in length, are used for ion- and plasma-jet systems research. A central exhauster system evacuates the tanks to 10^{-3} atmosphere and separate vacuum pumps further reduce the pressure to 10^{-3} atmosphere. A refrigeration system circulates liquid nitrogen through coils to cool the inner tank walls. The tanks for ion-jet research contain condenser plates for removing the ion-jet material.

Materials and Structures

Spacecraft Structures Facility

This facility provides for research on and preflight calibration of spacecraft and power plant structures. The building includes a large area for research on fabrication techniques and for structural and vibration tests on large-scale structures such as complete vehicles, propellant tanks, radiators, etc. Large, relatively low-capacity loading equipment, radiant-heating equipment, vibrators, and "soft" mounts are necessary research items for the main structural test area. Vehicle and radiator structural tests also require a large, refrigerated vacuum tank.

Launch, Rendezvous, Re-Entry, Recovery, and Flight Simulation

The launching facility is illustrated . . . for a seacoast location. The 10,000-foot separation between adjacent launching pads is conservative, even for high-energy propellants. The most hazardous operations will be confined to the central part of the site, and the less hazardous operations will be more uniformly distributed.

The launching facility may be combined with the static-test facility either (a) by placing the fuel-synthesis plants at the center of the exclusion circle and distributing the static-test and launching stands along the coast, or (b) by placing the static-test stands several miles inland along a line parallel to the seacoast.

A natural harbor is assumed. . . .

Launching facilities for chemical rockets. The launching site is provided with a number of launching facilities capable of handling rockets that have thrusts up to 1,000,000 pounds and that utilize either solid propellants or conventional or high-energy liquid propellants. In addition, a large platform with supporting equipment is provided for launching rockets with less than 150,000 pounds thrust. The site will accommodate more or larger launching facilities if required. . . .

Launching facilities for nuclear rockets. In the section on nuclear rocket research facilities, the large-scale static tests were to be conducted from an ocean or gulf site, making use of an underwater platform, an erection barge, a fuel barge, and a seagoing tug. A rocket disassembly building and a "hot" laboratory were provided at the harbor. These same items of equipment are intended to support the nuclear-rocket launching site. . . . However, it must be remembered that some platform locations suitable for static test may not be suitable for launchings. Nuclear rockets will probably require launching over several thousand miles of water in order to provide reasonable probability that the rockets will fall into a safe area in the event of an aborted flight.

Ship-borne launching and tracking facilities. The technique of shipboard launching and tracking is proposed to supplement rather than replace the shore-based facilities. This operation would stem from a continental base whose function would be to prepare and assemble the flight vehicles as well as to provide the necessary laboratory and logistic support. This home base might be the main launching site previously described.

Advantages of this system include remote launching with complete freedom of location and direction of firing. This permits freedom of choice of orbit, including equatorial orbits not attainable from the continental USA, and also increases the frequency with which rendezvous may be attempted with vehicles in orbits other than equatorial.

Whether launching is from sea or land, vessels still could serve as remote tracking stations, thus providing more freedom in choice of launching site and minimizing the need for locating tracking stations on foreign territory.

Guidance, communications, and tracking equipment, and range stations. The final guidance equipment is not well determined because of the rapid progress in this field. The number of range stations depends on the site and on the extent to which the Defense Department range stations can be shared. One new station should be in the vicinity of final-stage burnout and another in the southern hemisphere, to permit observing the apogee.

Guidance, computing, and instruments building. This building contains the offices of the scientific personnel at the launching site, the rocket-instrument test and development laboratory, and two digital computers. One computer would handle operational trajectory calculations and guidance problems of satellites during launching, rendezvous, orbit, and re-entry. The other would serve as a standby and would also perform data reduction and theoretical analyses of less urgent nature during this time.

Assembly shops. The shop is the largest building in the area. It would have area for work on approximately 10 large rocket assemblies at one time. The final assembly area would have a ceiling 200 feet high, with provisions for later increases, so that the rocket assemblies could be handled in a vertical position. Supporting fabrication and maintenance shops are included.

Supporting facilities. Additional supporting facilities required are a warehouse at the harbor, docking facilities, air strip, hangar, roads, tracks, utilities trench, fuel tank cars and trucks, sea water intake, and utilities buildings.

Measurements, Communication, and Guidance

Research in physical measurements, communications techniques, controls, guidance, and navigational instruments is closely interrelated. A group of four main laboratory buildings in close proximity with one another is required, along with one smaller complementary structure.

Guidance and controls systems laboratory. This laboratory will provide for adjusting, adapting, modifying, and testing control systems used in chemical- and nuclear-rocket power plants and in the associated research facilities; and for similar operations on guidance-control systems. In addition to conventional laboratory instrumentation for monitoring all variables, simulators and analog computers will be coupled to control elements through electromechanical links, in order to permit the complete systems analysis that necessarily precedes any extensive field tests.

Measurements and communications laboratory. This laboratory will be used for maintenance of primary laboratory standards, calibration of working standards, evaluation of measurement and communications equipment, adaptation of physical, meteorological, and engineering instruments to meet space, weight and environmental conditions imposed by the nature of the research project, and for instrument research that must necessarily be performed in close proximity to the other research activities it is intended to aid.

Computation and data-reduction laboratory. This laboratory will house facilities for performing intricate research computations by use of high-speed digital computers, relaxation nets, or simulators; for automatic data analysis by use of digital-analog computers; and for housing a central group of mathematicians to assist the research staff in short-term data analyses and research computations.

Instrumentation laboratory. In this laboratory, both commercial and NACA-developed instruments will be adapted, combined, and applied to form complete instrument systems for solution of the specific problems of the rest of the Laboratory. It will include facilities for simulating conditions of temperature, pressure, and acceleration to which instruments will be exposed in use; and the supporting facilities for instrument servicing.

A large whirling-arm facility, housed in a simple shed-type building, will be included to complement the acceleration-test facilities of the Instrumentation Laboratory, so that a complete space-cabin instrument assembly may be tested conveniently.

Space Mechanics and Space Environment

Space operations research facility. This building will provide for missions studies and for research on application of biological and medical equipment and techniques. A large area is provided for mock-up, assembly, and testing of research vehicles, exclusive of propulsion systems, prior to launching.

Space- and planetary-environment facility. This facility will allow simulation of outer-space conditions for research on and testing of instrument systems and equipment. A liquid-nitrogen-jacketed cylindrical tank capable of evacuation to ultra-high vacuum is provided. Alternatively, it will be possible to simulate atmospheric conditions on other planets. The chamber is equipped with access doors and observation windows, and has provisions for temperature and pressure variation.

Navigation and flight-simulation facility. This facility is for research on navigation techniques and pilot training. It will be a spherical structure with a star projector located at the center. A transparent horizontal floor will bisect the interior of the sphere; navigational- and control-equipment and pilot-training simulators will be installed near the center of the sphere.

Re-entry and rendezvous piloting simulator. This facility will provide means for research and development on vehicle controls and instrumentation, and for training pilots for the launching, rendezvous, and re-entry of vehicles traveling between ground and satellite orbit. The simulator is a centrifuge having a test cab with six degrees of freedom, and complete computing and servo-control positioners.

SECTION V

CONTRACTED RESEARCH

Timely solution of the many problems of manned space flight will require the immediate application of a number of scientific disciplines, some of which are not represented in the NACA's present research effort. In areas such as medicine, biology, astronomy, biophysics, and psychology, the NACA has neither performed any direct research nor has played any active role in directing and coordinating research efforts. In other research areas such as communication, guidance, and navigation, the NACA has used the end results of developments in these fields, but has not played an active role in producing these results or in contributing in any major way to the research effort.

It is necessary that the NACA develop competence in the application and use of these disciplines, and that it support the basic research that will lead to worthwhile developments in these areas. This support, in most cases, should take the form of direct work by the NACA; in other cases, this support can more effectively and economically be obtained by providing the NACA with the contractual authority to coordinate and to support financially the work of other existing groups. In a large number of areas, the end product of this contracted research would be a research report as has been the case in the past. In other research areas, the end product of the research effort may well be an item of hardware or research equipment, particularly since most of the areas of space flight research require extension of previous practice.

SECTION VI

ESTIMATES OF STAFF AND COSTS

An orderly and comprehensive program of NACA research on space flight technology, and the research facilities required to implement the program, have been outlined in the preceding sections.

The urgent need for a rapid buildup of national capability in space flight technology, leading to early flights of manned space vehicles, has been the most important consideration in organizing the program. Immediate expansion of the staff and facilities at existing NACA laboratories provides the earliest, best organized, and most powerful extension of national capability in space flight research. Limitations of existing laboratories as launching sites for space vehicles, and as sites for large propulsion-system research facilities, enforce concurrent construction of a new laboratory. To achieve early competence at the new laboratory, its nucleus will be drawn from the appropriately qualified staff of the existing laboratories.

The NACA will integrate in the program the talent and competence of qualified scientific groups outside its organization, by a greatly expanded program of contracted research.

Estimates of the staff and costs for the program are as follows:

1. The annual NACA operating budget for personnel, supplies, and equipment will be increased by 100 million dollars to provide for an increase in staff of 9,000 and for their support. This increase will provide for expansion of existing laboratories and for operation of a new laboratory. A two- to three-year period will be required to enlarge the staff to the target number.
2. Facilities for space flight research at the existing NACA laboratories will be augmented at an average annual rate of 55 million dollars for the next five years.
3. The facilities and equipment required for the new laboratory are estimated to cost 380 million dollars exclusive of the costs of the site. These funds will be expended in about a five-year period.
4. Research will be contracted to qualified organizations outside the NACA at an initial annual rate of 10 million dollars and, if necessary, increased above this rate as the research program develops.

NOTES

Appendix E

Unless otherwise indicated, all data on the NACA wind tunnels was derived from Donald D. Baals and William R. Corliss, *Wind Tunnels of the National Aeronautics and Space Administration* (SP-440; Washington: NASA, 1981).

1. Research and Development Board, Committee on Aeronautics, "U.S. and Foreign Wind Tunnels in Operation, under Construction, or Authorized," AR 26/11.5, 4 Feb. 1948.
2. The Working Committee of the Aeronautical Board, "Survey of Wind Tunnels," preliminary copy, 1 Jan. 1947.
3. Alan Pope, *Wind Tunnel Testing* (New York: John Wiley and Sons, Inc., 1947), pp. 16–29.
4. Bernard A. Goethart, *Transonic Wind Tunnel Testing*, ed. by Wilbur C. Nelson (New York: Pergamon Press, 1961), pp. 383–89.

Appendix F

1. The example of boundary-layer depth is drawn from John D. Anderson, Jr., *Introduction to Flight: Its Engineering and History* (New York: McGraw-Hill, 1978), pp. 123–24. I have drawn heavily on this excellent volume in preparing the discussion of the boundary layer. I have also profited greatly from the following works: Joseph Flatt, "The History of Boundary Layer Control Research in the United States," in G.V. Lachmann, ed., *Boundary Layer and Flow Control: Its Principles and Application* (2 vols.; New York, Pergamon Press, 1961), I, pp. 122–43; Hugh L. Dryden, "Exploring the Fundamentals of Aerodynamics," *Journal of the Washington Academy of Sciences* 37 (15 May 1947), 145–56; Neal Tetervin, "A Review of Boundary Layer Literature," NACA Technical Note 1384 (1947); and H. Schlicting, "Some Developments in Boundary Layer Research in the Past Thirty Years," *Journal of the Royal Aeronautical Society* 64 (Feb. 1960), 64–79.
2. Hugh L. Dryden, "Fifty Years of Boundary-Layer Theory and Experiment," *Science* 121 (18 Mar. 1955), 375–80. One reason for choosing "boundary layer" over "transition layer" was that transition came to be the preferred term to describe the change from laminar to turbulent flow.
3. The quote is from Anderson, *Introduction to Flight*, p. 118. The discussion here refers to incompressible flow, the kind experienced by an airplane traveling below the speed of sound. During most of the life of research authorization 201, even the air velocity over wings seldom exceeded the speed of sound.
4. Reid to engineer-in-charge, 2 Nov. 1926; Ide to George W. Lewis, 22 Sept. 1926; H. Lee Dickinson to Walter Bonney, "The Katzmayr Effect," 25 July 1956.
5. Engineer-in-charge to Munk, 3 Nov. 1926; Munk to engineer-in-charge, 4 Nov. 1926. On the importance of Munk, see Joseph Sweetman Ames, "A Resume of the Advances in Theoretical Aeronautics Made by Max M. Munk," NACA Report 213 (1925).
6. Lewis to Langley Memorial Aeronautical Laboratory (hereafter LMAL), 11 Nov. 1926. Evidence that this memo was prompted by Reid's attempt to present the idea directly to the Aerodynamics Committee is in Munk's memo, "Recommendation for new research," 16 Nov. 1926.
7. Munk, "Recommendation for new research."
8. Lewis to LMAL, 3 Dec. 1926; E.S. Land to NACA, 2 Dec. 1926.
9. Lewis to LMAL, 6 Dec. 1926.
10. J.W. Crowley to engineer-in-charge, 14 Dec. 1926; A. J. Fairbanks to engineer-in-charge, 10 Dec. 1926; George J. Higgins to H.J.E. Reid, 10 Dec. 1926; Thomas Carroll to H.J.E. Reid, 10 Dec. 1926.
11. Ide to NACA, 8 Dec. 1926; Crowley to H.J.E. Reid, 17 Jan. 1927; Katzmayr to Ide, 21 May 1927; Lewis to LMAL, 8 June 1927; H.J.E. Reid to NACA, 15 June 1927.

12. Munk to Lewis, "(Through official channnels)," 29 Jan. 1927; H.J.E. Reid to NACA, 31 Jan. 1927; Lewis to LMAL, 4 Feb. 1927; E.G. Reid to engineer-in-charge, 14 Feb. 1927; H.J.E. Reid to Munk, 3 March 1927, with Reid's subscript of 22 March 1927.
13. Max Sherberg to engineer-in-charge, 19 Jan. 1927; Lewis to LMAL, 19 Feb. 1927; George J. Higgins, Eastman Jacobs, and J.M. Shoemaker to engineer-in-charge, 15 Feb. 1927; Lewis to LMAL, 2 March 1927.
14. Thomas Carroll, "Preliminary Flight Tests of a Method of Boundary Layer Removal," 2 Sept. 1927; John W. Crowley, Jr. to H.J.E. Reid, undated; Reid to NACA, 10 Sept. 1927. Even though RA 201 stated that the suction technique was to be tested only in the wind tunnel, the first experiment run by the lab was a flight test.
15. J.S. McDonnell, Jr. to LMAL, 10 Oct. 1927; H.J.E. Reid to NACA, 14 Oct. 1927.
16. Lewis to LMAL, 23 Jan. 1928.
17. H.J.E. Reid to Lewis, 19 Jan. 1928; Lewis to LMAL, 23 Jan. 1928; Reid to NACA, 15 March 1929; Reid to NACA, 27 Aug. 1929.
18. Starr Truscott to Lewis, 25 June 1928; Lewis to LMAL, 2 July 1928, forwarding Karoku Wada, "Some Experiments on the Feathered Wing"; Reid to NACA, 9 March 1929; Thomas Carroll to Reid, 11 March 1929; Lewis to LMAL, 20 March 1929; Reid to NACA, 10 Sept. 1935. The chief test pilot referred to in this last letter was not Thomas Carroll but his successor, Melvin Gough.
19. Reid to NACA, 23 Aug. 1929; Reid to NACA, 1 Dec. 1930. An earlier report, Elliot G. Reid and M.J. Bamber, "Preliminary Investigation on Boundary Layer Control by Means of Suction and Pressure with the U.S.A. 27 Airfoil," NACA TN-286 (1928), was apparently the result of work done under a different research authorization.
20. Reid to NACA, 31 March 1931, forwarding I.H. Abbott, "Experiments with an Airfoil Model on Which the Boundary Layer Is Controlled without the Use of Supplementary Equipment"; Hugh B. Freeman, "Preliminary Report of the Measurement of Pressure Distribution on the ZRS-4 Airship Model," dated 25 Nov. 1931. Freeman observed in "Pressure-Distribution Measurements of the Hull and Fins of a 1/40-Scale Model of the U.S. Airship 'Akron,' " TR-443 (1932), that "experimental pressure-distribution results are . . . useful . . . indirectly, in computing the frictional forces on the surface of the hull." See also Hugh B. Freeman, "Measurements of Flow in the Boundary Layer of a 1/40-Scale Model of the U.S. Airship 'Akron,' " TR-430 (1932), which resulted from the same experiments.
21. Starr Truscott to engineer-in-charge, 5 April 1932; see also the correspondence between the NACA and the Bureau of Aeronautics between Dec. 1932 and March 1933, leading up to Lewis to LMAL, 5 May 1933.
22. Freeman to chief, Aerodynamics Division, 18 April 1932.
23. Reid to NACA, 18 April 1932; Lewis to LMAL, undated; Freeman to chief, Aerodynamics Division, 6 July 1932; Reid to NACA, 12 July 1932; Lewis to LMAL, 18 July 1932.
24. Eastman N. Jacobs to engineer-in-charge, "Notes on the history of the development of the laminar-flow airfoils and on the range of shapes included," 27 Dec. 1938.
25. Millikan to Lewis, 24 July 1933; Lewis to LMAL, 28 July 1933; Reid to NACA, 2 Aug. 1933.
26. Lewis to LMAL, 7 Nov. 1933.
27. Reid to NACA, 14 Nov. 1933.
28. Freeman to engineer-in-charge, 25 Jan. 1934.
29. Smith J. DeFrance to Elton W. Miller, undated; Donald H. Wood to Miller, 21 Dec. 1933; John W. Crowley, Jr., to Miller [ca. 28 Dec. 1933]; Fred E. Weick to Miller, 9 Jan. 1934; Freeman to Miller, 2 Jan. 1934; Reid to NACA, 25 Jan. 1934.
30. Lewis to LMAL, 5 April 1934; Reid to NACA, 13 April 1934. On the NACA families of airfoils, see George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), pp. 98–112. What the NACA was actually testing at the time were airfoil sections: i.e., cross-sections of wings and other airfoils cut from front to rear. In common parlance, however, many of the NACA engineers would refer to the section as simply an airfoil. On the subject of the NACA 2415, for example, the classic report (Ira H. Abbott, Albert E. von Doenhoff, and Louis S. Stivers, Jr., "Summary of Airfoil Data," TR-824 (1945)) says "the NACA 2415 airfoil has a 2-percent camber at 0.4 of the cord from the leading edge and is 15 percent [of the cord] thick."

The reasoning behind the NACA program to develop families of airfoil sections was revealed in Eastman N. Jacobs, Kenneth E. War, and Robert M. Pinkerton, "The Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Wind Tunnel," TR-460 (1933):

> The forms of the airfoil sections that are in common use today are, directly or indirectly, the result of investigations made at Göttingen of a large number of airfoils. Previously, airfoils such as the R.A.F. 15 and the U.S.A. 27, developed from airfoil profiles investigated in England, were widely used. All these investigations, however, were made at low values of the Reynolds Number; therefore, the airfoils developed may not be the optimum ones for full-scale application.

The NACA intended to remedy this shortcoming by developing its own family of airfoils based on tests in the variable-density wind tunnel, where high Reynolds numbers could be achieved.

31. The *Annual Report* for 1933 cited an investigation then under way on airfoil shapes:

> The results of this investigation were used to determine a thickness distribution for use in the development of cambered airfoils. Three cambered airfoils were tested; one of these, the National Advisory Committee for Aeronautics 216 airfoil, is superior at high speeds to both the Clark Y and R.A.F. 6 propeller airfoils having the same thickness. . . . The mean camber line corresponds to that of the National Advisory Committee for Aeronautics 24 series.

An earlier technical note had reported that slightly cambered airfoils like the 24 series were superior to comparable symmetrical wings (Eastman N. Jacobs and Kenneth E. Ward, "Tests of N.A.C.A. Airfoils in the Variable Density Wind Tunnel: Series 24," TN-404 [1932]) and another report two years later found a 24-series airfoil superior to all others tested at high speeds (John Stack and Albert E. von Doenhoff, "Tests of 16 Related Airfoils at High Speeds," TR-492 [1934]).

32. Freeman to chief, Aerodynamics Division, 21 April 1934; 11 June 1934; and 9 Oct. 1934.
33. Lewis to LMAL, 25 April 1934; and 15 June 1934.
34. Lewis's insistence on free discussion often made it difficult to determine where an idea originated. See H.J.E. Reid, "Notes for Dr. Hunsaker with reference to Dr. Lewis' part in establishing the Langley Laboratory," 4 Aug. 1948; and John V. Becker, "The High-Speed Frontier: Case Studies of Four NACA Programs, 1920–1950," NASA SP-445 (1980), p. 22.
35. P.E. Hemke to Lewis, 17 July 1934; Victory to LMAL, 24 July 1934. Reid replied for the laboratory that a tapered slot placed near midchord was the answer to questions one and two. There was no firm answer to three. A slight gain in lift over drag was experienced for coefficients of lift above .25, the gain increasing rapidly with coefficient of lift. This was due more to an increase in the coefficient of lift than to a reduction in drag. Reid to NACA, 27 July 1934.
36. Freeman to chief, Aerodynamics Division, 15 Nov. 1934; Frederick E. Weick to chief, Aerodynamics Division, 5 Dec. 1934; Jacobs to chief, Aerodynamics Division, 5 Dec. 1934; Reid to NACA, 4 Dec. 1934 [sic].
37. R.P. Lansing to Lewis, 19 March 1935; Freeman to Elton W. Miller, 2 April 1935; Donald H. Wood to Miller, undated; Reid to NACA, 3 April 1935; Lewis to Lansing, 5 April 1935.
38. Donald H. Wood to Elton W. Miller, 6 Feb. 1935.
39. Dated 20 March 1935. Remarks by the chief of the Aerodynamics Division were added to Wood's memorandum, over the date of 9 Feb.
40. Reid to NACA, 22 March 1935.
41. Helms to Lewis, 13 May 1935; Jacobs to Miller, undated; Freeman to chief, Aerodynamics Division, 15 May 1935.
42. Lewis to LMAL, 2 Aug. 1935; Helms to Lewis, 25 July 1935 and 29 July 1935.
43. Lewis to LMAL, 1 Aug. 1935.
44. Helms had cited in defense of his interpretation Millard Bamber's Technical Report 385. Freeman countered that Bamber's report had shown only that measured drag could be reduced by suction and blowing methods of boundary-layer control; it did not include the drag corresponding to the power consumed by the required blower. It was therefore inconclusive on the overall effect on drag. Reid to NACA, 5 Aug. 1935.
45. Reid memorandum for files, 15 Aug. 1935. With respect to Doenhoff's proposal for smoke-tunnel research on the boundary layer, Jacobs and Doenhoff agreed that such results must be conducted in a near-zero-turbulence tunnel, which the Langley laboratory then lacked.

46. Jacobs to engineer-in-charge, 21 Aug. 1935. The full paragraph on these reasons follows:

> 3. A number of factors contributing to this result may be mentioned, some of which have been neglected in past considerations of the problem:
>
> a. The saving in fuel weight owing to the higher speed.
> b. The saving in structural weight owing to reduced gust loads on the more heavily loaded wing and to reduced fuel and total weight, and to a somewhat reduced span.
> c. The saving in wing, tail, and fuselage cover weight.
> d. The saving in drag owing to reduced tail and fuselage areas resulting directly from the increased wing loading.
> e. The additional saving in wing drag owing to still further reductions of wing area made possible by the reduced weights.
> f. A small favorable wing-fuselage interference associated with a reduced span.
> g. A small drag saving accompanying increased Reynolds Numbers (based on airfoil chord) associated with the reduced span and higher speed, although the net effect is not favorable because the Reynolds Number is reduced by the area change.

Jacobs added to this memorandum the caveat that the results reported should "be considered strictly confidential and subject to revision."

47. Reid to NACA, 21 Aug. 1935; Smith J. DeFrance to engineer-in-charge, 31 Oct. 1935.
48. Reid to NACA, 17 Oct. 1935, forwarding von Doenhoff's report, which was published early the following year as Technical Note 544; Lewis to LMAL, 13 Sept. 1935; Reid to NACA, 18 Sept. 1935; Abe Silverstein and E. Floyd Valentine, memorandum report to engineer-in-charge, "Blocking Tests in the 20-Foot Tunnel," 13 Feb. 1936.
49. Smith J. DeFrance to chief, Aerodynamics Division, 10 June 1936.
50. Lewis to LMAL, 16 June 1936.
51. Von Doenhoff to chief, Aerodynamics Division, 30 June 1936; Jacobs to chief, Aerodynamics Division, 20 July 1936. This recommendation echoed the one that Jacobs and von Doenhoff had made the previous year in the conference on Freeman's proposed program of research. See note 42.
52. Reid to NACA, 11 Nov. 1936.
53. Reid to NACA, 19 Nov. 1937; Dryden to NACA, 14 Dec. 1937; Reid to NACA, 21 Feb. 1938. Von Doenhoff's report was published as TN-639 in March 1938.
54. Millikan to Lewis, 8 Feb. 1938.
55. Freeman to Donald H. Wood, 18 Feb. 1938; Wood to Elton W. Miller, undated; Smith J. DeFrance to Miller, undated; Reid to NACA, 28 Feb. 1938.
56. Jacobs to engineer-in-charge, undated [ca. 27 June 1938]. The low-turbulence tunnel had gone into operation at Langley the very month in which Jacobs sent his report to Reid, indicating that this was among the first projects to win tunnel time in the new facility. Low turbulence was obtained by screening the air in the tunnel and by increasing the contraction ratio: i.e., the ratio of the widest part of the tunnel to the lowest part, the test section. The old variable-density tunnel, with a contraction ratio of 4 to 1, had a 2-percent turbulence. By 1941 the NACA had a tunnel with a contraction ratio of 20 to 1 and turbulence of less than .015 percent. Two-dimensional flow was achieved by placing a wing section completely across the test section, to eliminate airflow anomalies at the wing tip and the wing-to-fuselage interface. See Gray, *Frontiers of Flight,* pp. 47–50.
57. Lewis to LMAL, 6 July 1938.
58. Reid to NACA, 13 Oct. 1938. Freeman left the NACA in 1939.
59. Reid to NACA, 6 Aug. 1938, in response to a letter from Vega Aircraft Company, requesting Freeman's results. Reid to NACA, 23 Sept. 1938; von Doenhoff's report was published as TN-671 the following month.
60. Albert E. von Doenhoff, "Investigation of the Boundary Layer About a Symmetrical Airfoil in a Wind Tunnel of Low Turbulence," Advance Confidential Report, Aug. 1940; J.W. Wetmore and J.A. Zalovcik, memorandum for files, "A Flight Investigation of the Boundary-Layer Characteristics and Profile Drag of the NACA 27-212 Laminar Flow Airfoil," 15 Aug. 1940; von Doenhoff and Neal Tetervin, "Investigation of the Variation of Lift Coefficient

with Reynolds Number at a Moderate Angle of Attack on a Low-Drag Airfoil," Confidential Bulletin, Nov. 1942; Wetmore, Zalovcik, and Robert C. Platt, "A Flight Investigation of the Boundary-Layer Characteristics and Profile Drag of the NACA 35-215 Laminar Flow Airfoil at High Reynolds Numbers," Memorandum Report, May 1941; Zalovcik, Wetmore, and von Doenhoff, "Flight Investigation of Boundary-Layer Control by Suction Slots on an NACA 35-215 Low-Drag Airfoil at High Reynolds Numbers," Advance Confidential Report 4B29, Feb. 1944, first submitted 8 April 1942.

61. Von Doenhoff to chief, Aerodynamics Division, 23 June 1942.
62. Lewis to LMAL, 20 July 1942; Reid to NACA, 26 Nov. 1942.
63. Lewis to LMAL, 19 Jan. 1943; Reid to NACA, 2 Feb. 1943; Lewis to LMAL, 8 Feb. 1943.
64. Reid to NACA, 29 April 1943; R.E. Littell to Lewis, 5 May 1943; Reid to NACA, 24 May 1943. This report (Albert E. von Doenhoff and Neal Tetervin, "Determination of General Relations for the Behavior of Turbulent Boundary Layers") was published in 1943 as Technical Report 772.
65. See Advance Confidential Report L4G14 of Feb. 1944 and Confidential Bulletin L4H10 of Aug. 1944; I.H. Abbott to chief of research, 19 Jan. 1945.
66. Lewis to LMAL, 8 Feb. 1945; S. Katzoff to chief of research, 20 Jan. 1945; Reid to NACA, 3 Dec. 1945, commenting on Dryden's letter of 8 Aug. 1945.

APPENDIX G

1. Eugene B. Jackson, chief, NACA Div. of Research Information, to Cyril W. Cleverdon, 29 Dec. 1953.
2. This, like other information presented here on advanced reports and on bulletins, is derived from George W. Lewis to Ames Aeronautical Laboratory, 22 June 1943.
3. George W. Lewis to Ames Aeronautical Laboratory, 6 Mar. 1943. As Lewis made clear in this memorandum, distinctions among the kinds of World War II reports were fuzzy even within the NACA. The terms *confidential, restricted, memorandum, bulletin,* and *report* were used loosely, and the descriptions of the various documents should not be taken too rigidly. Lines between confidential and restricted, and between bulletins and reports, were fine and shifting.
4. 57 A 415 (73), 53-2A, rejected reports.
5. F.H. Norton to George W. Lewis, 31 March 1922, and Lewis to Norton, 4 April 1922, both in 57 A 415 (2), 1-5A, 1919-1925.
6. John W. Crowley to NACA laboratories, 16 Oct. 1950, in 62 A 35 (73), 376, 8-12/1950.
7. See, for example, John F. Victory to George W. Lewis, 10 Jan. 1922, in 57 A 415 (66), 51-6G, 1921-1923; Lewis to John J. Ide, 3 Oct. 1929, ibid., 1927-1929; Langley laboratory to NACA, 30 March 1932, in 55 A 291 (4), RA 138; 57 A 415 (2), 1-5A, 1933-; and J.M. Shoemaker to Lewis, 10 Oct. 1927 (copy), in 55 A 344 (R4OZ), TN-284.
8. Lewis to Ide, 23 March 1929.
9. See R.J. Minshall to George W. Lewis, 7 May 1941, and Lewis to Minshall, 10 May 1941.
10. These figures, and those in the remainder of this appendix, were compiled by the author from the NACA indexes, 1949-1960. Year-by-year counts of all the Committee's technical reports in each subject area are available in the archives of this project (see bibliographic essay).

INDEX

The Author

Alex Roland graduated from the U.S. Naval Academy in 1966 with a B.S. in engineering. He spent the next four years in the Marine Corps, during which he served a tour of duty in Vietnam and earned an M.A. in American history from the University of Hawaii. From 1970 to 1973 he studied military history at Duke University, taking his Ph.D. in 1974. His dissertation was subsequently published as *Underwater Warfare in the Age of Sail* (1978). From 1973 to 1981 Roland was a historian with NASA, working on a number of projects in addition to this volume. In 1981 he returned to Duke, where he is currently associate professor of history, teaching military history and the history of technology.

The NASA History Series

Histories

Anderson, Frank W., Jr., *Orders of Magnitude: A History of NACA and NASA, 1915-1980* (NASA SP-4403, 2d ed., 1981).

Benson, Charles D., and William Barnaby Faherty, *Moonport: A History of Apollo Launch Facilities and Operations* (NASA SP-4204, 1978).

Bilstein, Roger E., *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (NASA SP-4206, 1980).

Boone, W. Fred, *NASA Office of Defense Affairs: The First Five Years* (NASA HHR-32, 1970, multilith).

Brooks, Courtney G., James M. Grimwood, and Loyd S. Swenson, Jr., *Chariots for Apollo: A History of Manned Lunar Spacecraft* (NASA SP-4205, 1979).

Byers, Bruce K., *Destination Moon: A History of the Lunar Orbiter Program* (NASA TM X-3487, 1977, multilith).

Compton, W. David, and Charles D. Benson, *Living and Working in Space: A History of Skylab* (NASA SP-4208, 1983).

Corliss, William R., *NASA Sounding Rockets, 1958-1968: A Historical Summary* (NASA SP-4401, 1971).

Ezell, Edward Clinton, and Linda Neuman Ezell, *The Partnership: A History of the Apollo-Soyuz Test Project* (NASA SP-4209, 1978).

Green, Constance McL., and Milton Lomask, *Vanguard: A History* (NASA SP-4202, 1970; also Washington: Smithsonian Institution Press, 1971).

Hacker, Barton C., and James M. Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (NASA SP-4203, 1977).

Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (NASA SP-4210, 1977).

Hartman, Edwin P., *Adventures in Research: A History of Ames Research Center, 1940-1965* (NASA SP-4302, 1970).

Levine, Arnold, *Managing NASA in the Apollo Era* (NASA SP-4102, 1982).

Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (NASA SP-4211, 1980).

Rosenthal, Alfred, *Venture into Space: Early Years of Goddard Space Flight Center* (NASA SP-4301, 1968).

Rosholt, Robert L., *An Administrative History of NASA, 1958-1963* (NASA SP-4101, 1966).

Sloop, John L., *Liquid Hydrogen as a Propulsion Fuel, 1945-1959* (NASA SP-4404, 1978).

Swenson, Loyd S., Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (NASA SP-4201, 1966).

REFERENCE WORKS

Aeronautics and Space Report of the President, annual volumes for 1975-1982.
The Apollo Spacecraft: A Chronology (NASA SP-4009, vol. 1, 1969; vol. 2, 1973; vol. 3, 1976; vol. 4, 1978).
Astronautics and Aeronautics: A Chronology, annual volumes 1961-1976 with an earlier summary volume, *Aeronautics and Astronautics, 1915-1960.*
Dickson, Katherine M., ed., *History of Aeronautics and Astronautics: A Preliminary Bibliography* (NASA HHR-29, 1968, multilith).
Hall, R. Cargill, ed., *Essays on the History of Rocketry and Astronautics: Proceedings of the Third through the Sixth History Symposia of the International Academy of Astronautics* (NASA CP-2014, 2 vols., 1977).
Hall, R. Cargill, *Project Ranger: A Chronology* (JPL/HR-2, 1971, multilith).
Looney, John J., ed., *Bibliography of Space Books and Articles from Non-Aerospace Journals, 1957-1977* (NASA HHR-51, 1979, multilith).
Roland, Alex F., *A Guide to Research in NASA History* (NASA HHR-50, 7th ed., 1984, available from NASA History Office).
Skylab: A Chronology (NASA SP-4011, 1977).
Van Nimmen, Jane, and Leonard C. Bruno, with Robert L. Rosholt, *NASA Historical Data Book, 1958-1968,* vol. 1, *NASA Resources* (NASA SP-4012, 1976).
Wells, Helen T., Susan H. Whiteley, and Carrie E. Karegeannes, *Origins of NASA Names* (NASA SP-4402, 1976).

Recent volumes are available from Superintendent of Documents, Government Printing Office, Washington, DC 20402; early volumes from National Technical Information Service, Springfield, VA 22161.

☆ U.S. GOVERNMENT PRINTING OFFICE : 1985 O - 470-422 Vol.2 : QL 2

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No
NASA SP-4103		

4. Title and Subtitle	5. Report Date
Model Research: The National Advisory Committee for Aeronautics, 1915-1958	6. Performing Organization Code LBH
7. Author(s) Alex Roland	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address History Office National Aeronautics and Space Administration Washington, D. C. 20546	11. Contract or Grant No.
	13. Type of Report and Period Covered Special Publication
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The National Advisory Committee for Aeronautics, the predecessor of NASA, was the premier aeronautical research organization in the United States. It conducted "scientific study of the problems of flight with a view to their practical solution." This institutional history traces the birth and evolution of the NACA and analyzes such recurrent themes as the roles of science and engineering, the influence of politics on technology, the way in which the institution shapes technology and technology shapes the institution, the contributions of key individuals, the nature of the research process, and the relation between military and civilian aviation. Appendixes provide comprehensive data on personnel, organization, funding, research programs, and publications.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
aerodynamics boundary-layer control NACA engines wind tunnel	Unclassified--Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	750	

N-305

For sale by the National Technical Information Service, Springfield Virginia 22161

Model Research: The National Advisory Committee for Aeronautics, 1915-1958
NASA SP-4103

by Alex Roland

Narrative history of the National Advisory Committee for Aeronautics, 1915-1958. This agency, the predecessor of NASA, was the premier aeronautical research organization in the United States, conducting "scientific study of the problems of flight with a viewto their practiacl solution." This instituional history traces the birth and evolution of the NACA and anayzes such recurrent themse as the roles of science and engineering, the influence of politics on technology, the way in which the institution shapes technology and technology shapes the institution, the contributions of key individuals, the nature of the research process, and the relation between military and civilian aviation. Appendixes provide comprehensive data on personnel, organization, funding, research programs, and publications.