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NASA'S ROLE IN AERONAUTICS: A Workshop

Volume II Military Aviation

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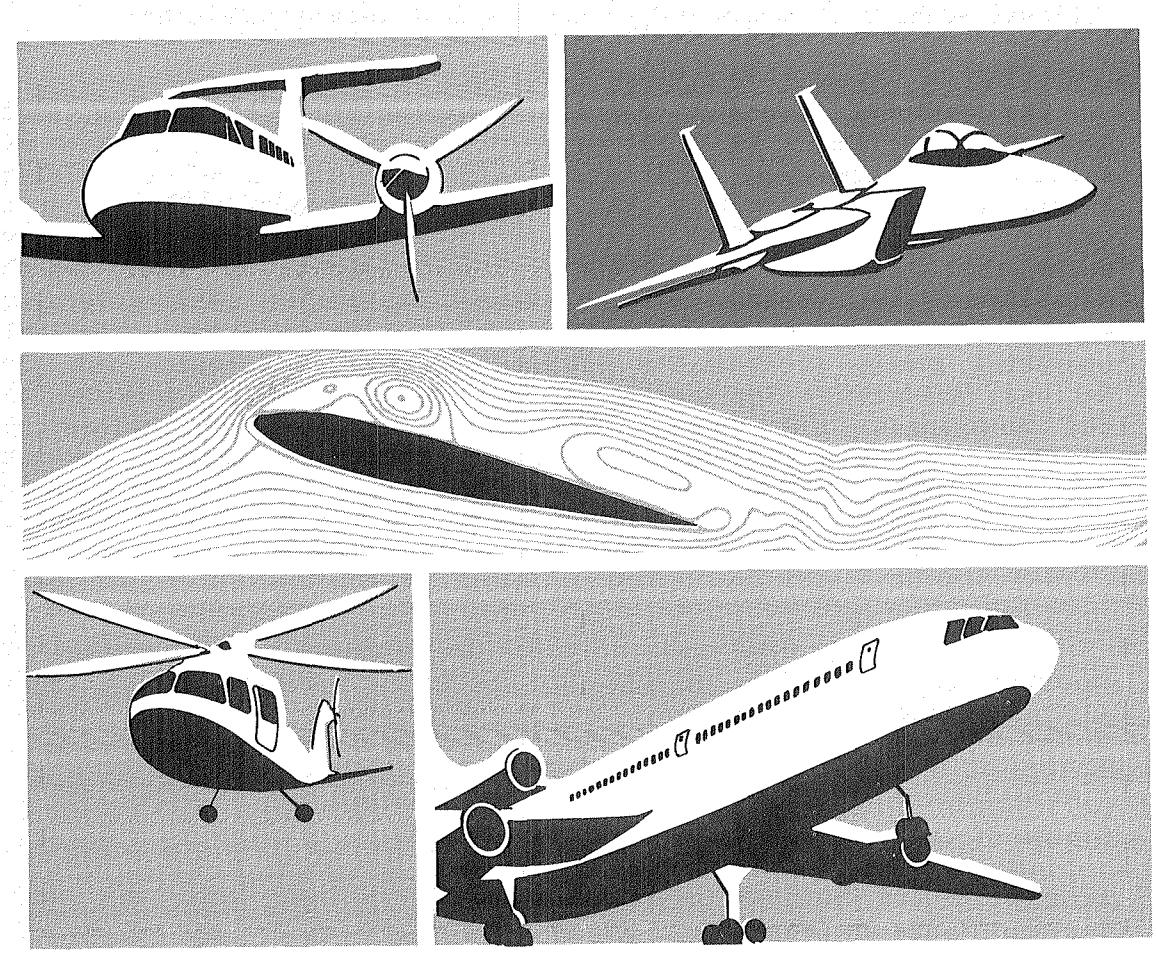

Report to the Workshop by the Panel on Military Aviation
Aeronautics and Space Engineering Board
Assembly of Engineering
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

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PREFACE

Aeronautics is changing in many significant respects. The implications of this are so far-reaching as to call into question the future position of the United States in world aviation.

The magnitude of this question, with its possible consequences for the nation's economy and security, led the National Aeronautics and Space Administration (NASA) to seek an independent evaluation from the Aeronautics and Space Engineering Board (ASEB) of the National Research Council's Assembly of Engineering. Specifically, the ASEB was asked to assess the nature and implications of the current state of U.S. aviation in a world setting and their significance for NASA's role in the nation's aeronautical future.

The ASEB responded by convening a workshop July 27 through August 2, 1980, at the National Academy of Sciences' Woods Hole Study Center. The workshop was structured into four panels covering military aviation, transport aircraft, general aviation, and rotorcraft. In addition, an overview panel was formed to consider NASA's role in research as well as its relationships with other elements of the aeronautics community.

The central task of the workshop was to examine the relationship of NASA's aeronautical research capabilities to the state of U.S. aviation and to make recommendations about NASA's future roles in aeronautics.

NASA and its predecessor, the National Advisory Committee for Aeronautics (NACA), traditionally have maintained a cooperative relationship with the aeronautical industry, with other government agencies concerned with aircraft operations and regulations, and with the academic community engaged in aerospace research. This triumvirate was taken into account in planning the workshop and selecting the participants. Thus, representatives from each part of the aeronautical community were invited, and information on NASA's relationship with each was the subject of special presentations prior to the working sessions. Representation from industry was predominant because industry's relationship with NASA is considered to be a key element in examining the present and future roles of NASA.

The members of the workshop panels represented, in total expertise and experience, all of the important sectors of aeronautics: military aircraft and missiles; commercial air transports; general aviation;

rotorcraft; university and private research; airline operations; and government regulatory agencies. In addition, the participants also included representatives of other industries--notably, automotive, electronics, and steel. Including the speakers and other non-panel members, close to 80 individuals participated.

The participants were asked to address the issue of NASA's role in the context of a wider discussion concerning: the status and dimensions of U.S. aeronautics; the key aeronautical problems and opportunities that are likely to be amenable to research and technology development; the historical evolution and accomplishments of NASA in aeronautical research and technology development; and possible alternatives to NASA. Each of these subjects is discussed thoroughly in separate panel reports.

The report of the workshop consists of seven volumes:

I -- Summary

II -- Report of the Panel on Military Aviation

III -- Report of the Panel on Transport Aircraft

IV -- Report of the Panel on General Aviation

V -- Report of the Panel on Rotorcraft

VI -- Report of the Overview Panel on Aeronautical Research

VII -- Background Papers--The Outlook for Aeronautics and Relevant Areas

In order to help focus the discussion, NASA officials developed and provided a concise set of definitions of eight possible roles for NASA: National Facilities and Expertise; Research; Generic Technology Evolution; Vehicle Class Technology Evolution; Technology Demonstration; Technology Validation; Prototype Development; and, Operations Feasibility. Because some of these roles differ, depending on the aeronautical discipline involved, the roles are assessed within six principal aeronautical disciplines: aerodynamics, structures and materials, propulsion, electronics and avionics, vehicle operations, and human engineering. Definitions of these roles and disciplines are contained in Appendix B. The matching of the roles and disciplines is treated in Volumes II-VI and summarized in Section II of Volume I.

The workshop participants were extensively briefed by officials from NASA, the Department of Defense (DOD), and the Federal Aviation Administration (FAA), by leaders from the aviation manufacturing and operating industries, and by a member of Congress. The briefings are to be found in Volume VII.

Each panel separately considered the national benefits produced within the dimensions of its sector and the relative state of the sector's world position; each considered the evolution of NASA's role,

as well as a rationale for NASA's aeronautical support of its sector; and, finally, each panel produced sector-oriented conclusions and recommendations for NASA's roles for the future. Although there are obvious overlaps, the similarities and differences in each of the panels' findings are preserved in the separate reports of the sector-oriented panels, Volumes II-V.

This document, Volume II, presents the findings and recommendations of the Panel on Military Aviation.

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INTRODUCTION

Critical to the nation's security, military aircraft and missiles are designed to gain air superiority, to interdict the movements of troops and materiel, to augment and direct ground and sea-based fire power, to perform reconnaissance, to protect sea lanes, to provide strategic deterrence, and in the case of aircraft, to move troops and supplies. If the United States is to defend itself successfully, U.S. aircraft and missiles must be adequate to accomplish these tasks. The United States lags behind its principal potential adversary, the U.S.S.R., in numbers of planes and missiles. Therefore, the United States has adopted a policy of qualitative superiority to counterbalance its numerical inferiority.

Today, the United States must rely on the capabilities of its allies to complement its air power. Although most of post-World War II aircraft, armament, and equipment in non-Communist nations have come from U.S. industry, much of the equipment for replacement and retrofit are likely to be designed and manufactured either by foreign countries or transnational consortiums. The NATO nations and Japan have concentrated on building aeronautical research capabilities during the last 15 years, and today their aggregate research facilities are equivalent to those of NASA. The result of all this is that foreign-made aircraft and missiles now reflect technology that is more or less equivalent to U.S. designs.

The U.S.S.R. continues to expand and modernize an extensive array of military airplanes, missiles, and armament as a part of a coherent and continuing national policy to achieve superiority over the Western alliance of nations. Efforts are being made to increase both the quantity and the quality of Soviet aircraft. The U.S.S.R. has achieved numerical parity in tactical aircraft through production that exceeds the combined U.S. and European rates. The development of both

new technology aircraft and derivative models is given high priority in the U.S.S.R.

The U.S.S.R. and the Warsaw Pact nations now have tactical aircraft with greater capabilities, including longer ranges, expanded external weapons carriage capacity, and improved delivery systems. Ground forces are supported by a formidable system of highly mobile surface-to-air missiles, rapid-fire machine guns, and conventional anti-aircraft cannons. All are linked by an excellent command-control-communications network. Defense elements include aircraft with airborne warning and control systems and high performance interceptors with a look-down/shoot-down capability to defend against low-altitude bombers and cruise missiles.

U.S.S.R. naval aviation comprises a mix of long-range patrol aircraft and intermediate-range supersonic bombers equipped with air-to-surface missiles. High performance, fixed-wing Vertical and/or Short Takeoff and Landing (V/STOL) aircraft, capable of operating from moderate-sized ships, are currently operational in the U.S.S.R. air fleet. Mobile forces use both fixed-wing and rotory-wing aircraft capable of conducting a fast, massive airlift operation. Helicopter operations now feature armed gunships. In all, the evidence points to the continuing development of Soviet airpower, plus a continuation of its willingness to supply modern, high performance aircraft to Third World nations.

The U.S. military services depend on a strong complementary aeronautical technology base in NASA, industry, and academe to supplement their efforts. NASA aeronautical technology developments, in particular, are vital to the Department of Defense (DOD) in the performance of its basic mission of successfully defending the United States against adversaries. Therefore, it is appropriate to consider the specific roles that NASA could or should play in support of the defense of this nation.

STATUS AND DIMENSIONS OF THE U.S. MILITARY AERONAUTICAL COMMUNITY

For the purposes of this report, "Military Aeronautics" refers to all fixed-wing military airplanes and all aerodynamic missiles. Thus, ballistic missiles are not discussed here, and military rotorcraft are included in Volume V.

Fixed-wing military aircraft and aerodynamic missiles are produced in the United States by a large industry consisting of prime contractors for aircraft, engines, and missiles, as well as thousands of subcontractors. Many of these manufacturers produce products for both the military and the commercial markets.

The U.S. industry possesses capabilities from research to production of military aircraft. The estimated 1980 sales of military aircraft and components will amount to $15 billion. The customers for this market are the military services of the U.S. government and the defense establishments of America's allies and some other nations. Foreign governments spent between $2 and $4 billion per year during the decade of the 1970s on military aircraft produced by U.S. companies.

Historically, the assignment of specific responsibilities to either the DOD or NASA for tasks related to aeronautical research, technology development, and flight testing has led to rapid advances in U.S. military aviation. The military maintains facilities required for both missile and aircraft flight testing and evaluation. In addition, it maintains some specialized facilities required for aerodynamic and propulsion testing. NASA conducts aeronautical research at the Langley, Ames, Lewis and Dryden Research Centers. These facilities possess unique capabilities to serve both military and civil aeronautics programs.

In addition to the aeronautical technology program supported by the industry/military/NASA team, some of the nation's leading universities make major contributions in aeronautical research for military applications. Most university programs are government supported, although recently there has been an increase of industrial support for university programs in military aeronautics.

The total spent on aeronautical research, development of generic technology, and development of vehicle class technology by industry, the military, NASA and academe for military aircraft is likely to run to $750 million in 1980. In addition, nearly $2 billion of Research, Development, Test, and Engineering (RDTE) is funded by the DOD for aircraft and related equipment.

During recent years, industry, government, and academe have been caught in a downdraft for military aircraft. Greater sophistication of weapon systems and high inflation rates have led to an increase in military R&D and procurement costs. Moreover, changing national priorities have increased greatly the share of the federal budget allocated for human and social programs and severely decreased the share allocated for defense programs (see Volume I, Figure 1).

Increased technological sophistication has made new demands on industry to invest in facilities such as simulators, water tunnels, and environmental and avionics integration laboratories. This, in turn, has led to a higher ratio of engineers to factory workers. In addition, some factory operations are changing from fabricating and assembling aluminum parts to processing graphite composite materials to form structures, or machining and assembling metals by computer-programed machines. Through the use of computer-aided design, computer-aided manufacturing and robotics, the industry is heading for much more automation.

The lead time required to develop military aircraft has more than doubled during the last two decades. This is due, in part, to the increasing sophistication of weapons systems. Increased complexity of governmental decision processes and administrative procedures has also been important in extending the leadtime between design and use.

As noted in Volume I, Appendix A, conditions at NASA are changing. The technical staff is being eroded because key members are aging and civil service manpower ceilings are being lowered. Also, NASA seems to have difficulty attracting young engineers and scientists. The older NACA facilities, which were the best in the world when installed, are becoming obsolete because funds are lacking to upgrade them. This has led to a decrease in the output of data by NASA, as compared with the output from newer foreign facilities. Finally, NASA's flexibility in using its wind tunnels is affected by higher costs for electrical power.

The nation's ability to react to any perceived military threat and to fulfill commitments to its Allies is limited, among many things, by the high cost of aircraft and weapon systems, as well as by the ever-increasing length of the development cycle of such hardware. The development cycle is now at least 10 years long, as measured from the identification of a military need to the initial realization of an operational capability. The situation can be countered by technology advances directed toward cost reduction and performance improvement, as well as by providing a technology base mature enough for exploitation with minimal development risk. NASA's efforts on these fronts are likely to benefit the nation's defense posture.

MILITARY AERONAUTICAL RESEARCH AND TECHNOLOGY NEEDS

The military aerospace forces of the future will include atmospheric systems, space systems, and ballistic missile systems. This section deals with the aeronautical technology needs for atmospheric systems.

Future military missions will make demands on aircraft calling for great improvements over today's capabilities. The new aircraft will need to possess such characteristics as affordability/supportability, survivability/sustainability, and fuel economy. In addition, improved aircraft must have the performance capability to meet the classic mission requirements. Advances in avionics and weapon systems are essential to counter present and future threats. Such improvements need to be complemented by a broad range of aeronautical technology advances to achieve the necessary levels of improvement in essential aircraft characteristics. The trade-off nature of aircraft design to meet specific mission requirements demands a technology level adequate to permit trade-off decisions. For example, engine turbine materials suitable for operations at higher temperatures than possible with current materials are required to allow a trade between performance at higher temperatures and durability at lower temperatures, without excessive degradation in either range.

Affordability and supportability impose direct requirements for: 1) improved materials/structures at comparable material and manufacturing costs to reduce the weight and size of the aircraft; and 2) propulsion and aerodynamic advancements that reduce both the powerplant weight and the fuel required for a given mission. Reliability and durability of the airframe, engine, and systems also must be increased through applications of improved materials and innovative mechanical concepts.

Survivability and sustainability, which are considered vital to combat effectiveness beyond the initial engagement, require advanced materials and structural concepts to withstand damage sustained in

combat and to enhance maintenance and repair, even while reducing logistic support requirements. Survivability also can be enhanced greatly by reducing both radar and infra-red (IR) signatures. Techniques are needed to reduce these signatures with minimum aerodynamic and structural penalties. Both engine and nozzle technologies offer potential for reducing IR signatures, but significant development is needed to minimize performance degradation. Potential runway denial requires Vertical and/or Short Takeoff and Landing (V/STOL) aircraft or other innovative solutions to permit sustained flight operations.

Fuel economy places additional emphasis on technology to reduce viscous drag. Improving the efficiency of operational systems also enhances fuel economy. This can be done through human factors research in workload assessment and operator/system interfacing, as well as by the use of alternative training systems.

Mission performance needs are escalating. These include increased range to provide a self-deployment capability and to be free of a requirement for tanker refueling support, as well as to meet the non-NATO contingency requirements. Progress needs to be made in the areas of structures, aerodynamics, and propulsion to offset the alternative of significantly increased aircraft size.

Technology for efficient supersonic cruise military applications should be developed even though there now is no well-defined military need. Development of such technology could enhance the nation's defense preparedness by enabling tactical aircraft to meet the threat of a growing number of Soviet tactical aircraft and bombers. Missile applications would provide increased survivability for cruise missiles, plus greater lethality for tactical missiles. The greater responsiveness provided by higher speed would be a valuable asset for a military commander. Other less well defined applications include interceptors and reconnaissance vehicles, as well as long-range interdiction aircraft.

V/STOL aircraft not only will require specialized technology development, but also will benefit from broad advances in aeronautical technology because of their extreme sensitivity to weight. Specific technology requirements of V/STOL aircraft include propulsive lift systems yielding the highest attainable thrust for a given propulsion weight; aircraft control during hover and at low speeds, particularly under instrument-flight conditions; and advanced structural materials and design concepts to reduce the structural weight of aircraft.

Missiles constitute a major element of modern airpower. The intensive, interlinked defense network established by the U.S.S.R. has greatly increased the importance of longer stand-off range capability for both tactical and strategic situations. Moreover, advanced fighters and bombers place increased technology requirements on air-to-air missiles.

Current air-launched missiles have restricted launch and firing envelopes, create high carriage drag, and penalize aircraft range and maneuverability. Accordingly, the need exists for significant improvements, including advanced hybrid propulsion systems, as well as

new configurations that will increase propulsive and lift/drag efficiency and provide a significant extension of stand-off capabilities. At launch, severe aerodynamic interference may cause the missile to collide with the launch aircraft or to lose its "seeker lock-on" or flight control capabilities. The high angle-of-attack flight during the "end-game" results in highly nonlinear forces and severe roll-yaw coupling that tax the capabilities of the missile guidance system and often limit the maneuver envelope. Thrust vector control and air slew concepts offer the potential for an effective all-aspect "kill" envelope. A systematic design data base is needed to reduce costly testing.

Other areas are equally important. Structural weight is a significant percent of total launch weight. Application of advanced materials and structural concepts could reduce this weight, thereby reducing total carriage weight and improving maneuverability. Use of advanced flight control systems offers the potential of eliminating launch envelope restrictions.

Remotely Piloted Vehicles for military missions range from simple drones to very high altitude atmospheric flight vehicles capable of extended operations. Very lightweight structures are essential for the latter. Flights of long duration require new and efficient power systems with low energy consumption and aircraft configurations for flight at very low Reynolds Numbers. Low-cost technology is the driving element for the simple drone.

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EVOLUTION OF NASA'S CURRENT ROLE IN MILITARY AERONAUTICS

In 1915 the Congress established the National Advisory Committee for Aeronautics (NACA) in reaction to the advances of military aircraft made by Britain, Germany, and France in World War I. A centralized national effort was considered necessary, and the NACA charter was aimed at solving problems of military aircraft, largely because civil aviation was essentially non-existent in 1915. Through the 1930s, NACA research was fundamental in nature, and the military was its principal user. This association continued through the 1950s, advancing the exploration of the frontiers of flight from the X-1 to the X-15. Generally, advances in technology were applied to military aircraft well before they were applied to civil aircraft. NACA's role in civil aviation was primarily in support of airworthiness--e.g., the development of gust-load criteria and landing-load criteria, rather than basic disciplinary research directed toward the specific needs of transport or general aviation aircraft.

Another important aspect of NACA's role in military aeronautics was the way the organization functioned. The NACA was a committee of experts from all segments of the aeronautical community, who, through a sub-committee system, considered the major problems in the aeronautical disciplines. Military members of the committee and subcommittees represented Army and Navy aviation research and development and, later, Air Force R&D. Thus, NACA tended to be the de facto principal aeronautical research arm of the military services, and the pattern of NASA's role in military aeronautics was established.

When NASA was being organized in 1957-1958, President Eisenhower directed the Secretary of Defense and the Chairman of NACA to ensure that the new agency would continue to perform for the DOD those services in support of military aeronautics that NACA had provided in the past. (Mr. Eisenhower's memorandum, dated April 2, 1958, is Appendix A of this Volume.) While the National Aeronautics and Space

Act of 1958 establishing NASA makes the DOD primarily responsible for military aeronautics, it stipulates a role for NASA in providing direct and indirect support to the DOD.

During the 1960s and the 1970s, NASA's aeronautical activities were gradually transformed from a predominantly military orientation to one that was more than 85 percent civilian. This occurred as the needs of the civil side of aviation began to diverge from those of the military. However, a cadre of scientists, engineers, and technicians at Langley, Lewis, and Ames continued to work on the development of advanced military aircraft technologies, to support direct military requests and to conduct joint NASA-DOD programs. At Dryden, more than half of the staff continued to be engaged in military-oriented aeronautical activities.

The broader scope of NASA programs results in a greater diversity of approaches to specific technical problems. Whereas the DOD programs generally develop specific or "design point" solutions, NASA results are usually more parametric and generic in nature and much less constrained by the need to meet specific vehicle requirements. Thus, they can be applied to a much wider range of flight regimes and flight problems.

Out of a total NASA aeronautical research and technology (R&T) budget of $308 million in FY 1980, $39 million was directed toward military aircraft research (excluding rotorcraft). An additional $24.3 million is for projects that are equally applicable to military and civil systems of the future, such as supersonic cruise and hypersonics. (This R&T budget does not include salaries, travel costs, construction of facilities, and such operating expenses as utilities.) Of NASA's total of 3,733 man-years for in-house staff directly engaged in aeronautics, 665 are involved in military programs and an additional 465 are engaged in activities with potential military applications.

Table 1 shows R&D dollars (as budgeted) and manpower for the total NASA aeronautical program, the uniquely military activities, and the areas potentially applicable to military needs from FY 1975 to FY 1980. Table 2 lists the direct man-years at the various NASA centers engaged in uniquely military program activities. Table 3 provides information on the direct man-years at the NASA centers engaged in activities of potential military application. Table 4 is a representative list of major military programs conducted by NASA on behalf of the DOD in FY 1980.

In terms of numbers of aircraft, the current military strength of the United States is inferior to that of the U.S.S.R. The policy of the DOD is to offset this deficiency by providing U.S. forces with weapons of superior quality and capability. Therefore, the quality of our military aircraft and the technical data on which they are dependent for their design are matters of crucial importance.

Because the NASA research centers and their scientific staffs have been developed over a period of years, they are able to provide continuity of effort, facilities to undertake tasks requiring long lead times, and teams of specialized scientists and engineers. The

TABLE 1 NASA Aeronautics Program Resources–Total vs Uniquely Military and Potentially Applicable to Military

Fiscal Year	1975	1976	1977	1978	1979	1980
Total Aero						
R&D ($ M)*	166.4	175.4	190.1	228.0	264.1	308.3
DMY†	3,824	3,734	3,708	3,887	3,723	3,733
Uniquely Military (excluding rotorcraft)						
R&D ($ M)	22.9	28.5	32.9	35.2	38.2	38.7
DMY	610	605	625	660	670	665
Potentially Applicable to Military						
R&D ($ M)	21.3	18.9	20.1	20.3	21.0	24.3
DMY	465	440	450	450	460	465

*This R&D budget does not include salaries of personnel, travel, or certain operating expenses such as utilities and construction of facilities.
†DMY Direct Man Years.
Source: NASA.

TABLE 2 Uniquely Military Activities–FY 1980 Direct Man Years (excluding rotorcraft)

Langley - 188		Dryden - 239	
Flutter Suppression	9	RPRV Technology	5
Flight Dynamics	23	Flight Dynamics	7
HiMAT	6	Support A/C	43
Combat Vehicles and Missiles	90	AFTI-111	17
Maneuvering Aero	9	AFTII-16	14
Propulsion Systems Integration	10	F-14	23
Direct Request	41	HiMAT	48
		Interact	5
Ames - 122		Hi Speed Aero	5
Flight Dynamics	11	F-15	26
Propulsion/AF Integration	6	KC-135	20
VTOL	61	T-38 Tail	4
Direct Request	44	Direct Request	22
Lewis - 116			
Combat Vehicles	17		
Structural Dynamics	16		
Propulsion Controls	2		
Engine Dynamics and Controls	45		
VTOL Propulsion	5		
Direct Request	31		

Source: NASA.

TABLE 3 Activities Potentially Applicable to Military—FY 1980 Direct Man Years

Langley - 185		Lewis - 205	
Config. Aerodynamics	25	Inlet and Nozzles	36 (Partial)
Hypersonics	85	Fan, Comp. and Turbine	50 (Partial)
Composite Materials	20 (Partial)	Power Transfer	32 (Partial)
Structural Dynamics	10 (Partial)	Engine Materials	40 (Partial)
Control Technology	5	Fracture Fatigue	10 (Partial)
Simulator Technology	3	Composites	12 (Partial)
Supersonic Cruise	31 (Partial)	Variable Cycle Engine	9 (Partial)
Miscellaneous	6	Miscellaneous	16
Ames - 48		Dryden - 27	
Simulator Technology	15	Flight Loads	12
Fuel Tank	3	Hypersonic Structures	5
Generic VTOL	25	Unsteady Aerodynamics	5
Miscellaneous	5	Miscellaneous	5

Source: NASA.

TABLE 4 Major Military FY 1980 Programs Performed by NASA (excluding rotorcraft)

HiMAT	F-18 Drag Improvement	T-38 Tail
KC-135 Winglet Demo.	Missile Aerodynamics	2-D Nozzle
Stall/Spin	VTOL Aero and Prop. Tech.	Fighter Aero
F-14 Aileron/Rudder Interconnect	AFTI	Direct Requests

Source: NASA.

working relationships among the DOD, industry, and NASA have led to generally smooth and successful research and development efforts. Independently and on its own initiative, NASA conducts research of use and value to the military.

For two particular DOD mission categories, utility and transport aircraft, NASA provides virtually all of the U.S. government technology development effort. The DOD relies heavily on NASA for technology development for cargo aircraft, and a significant amount of this work also is applicable to bomber aircraft. In late 1979, NASA activity in the development of primary composite aircraft structures for long-range

aircraft was curtailed, while the hazards of the release of fibers in the atmosphere in the event of a crash and fire were assessed. Although it was concluded that no significant hazard exists, the slowdown of research on such materials is likely to have an adverse impact on the development of military airlift aircraft in the future.

In addition, with no exchange of funds, NASA technical personnel currently assist the DOD in all phases of aircraft development. In the area of preliminary design, NASA staff help with performance prediction assessment. This activity is sometimes intensified when manufacturers are required to submit wind tunnel models to NASA for independent evaluation. During DOD engineering development, NASA often is called upon to provide expert advice and to solve problems that arise particularly during the flight test phase. When significant operational problems have occurred with aircraft in service, NASA assistance to the DOD has been critically important. Examples include: 1) problems related to the external carriage of ordnance when the requirement was not anticipated in the original design of the aircraft; 2) changes in flight regime required by changed operational needs, such as low altitude penetrator flight patterns for the B-52; and 3) developments required to improve stall/spin characteristics. Such development testing activity benefits NASA by providing first-hand knowledge of military needs and insights into problems associated with the application of new and advanced technology. The cooperative relationship in which NASA's efforts are conducted with its own budget and are not dependent on the DOD for support permits NASA to maintain its independence and objectivity in serving the DOD.

Similarly, by contributing to the superiority of such U.S. military products as new weapons systems, NASA helps to make the products more competitive with or superior to similar ones developed by other countries. This adds directly to U.S. security and to the U.S. industry's total market. As a result, the U.S. product may be produced in greater numbers and at lower unit cost, with consequent savings to U.S. taxpayers. If these products or systems are sold abroad, the U.S. balance of payments is improved, further assisting the economy.

The various segments of NASA communicate well with industry, the military, academe, and among themselves. Also, because of its broad access to research data, NASA is in a position to provide trend studies and summary assessments. When appropriate, industry and others are given access to military research results that otherwise might not be available because their existence would not be generally known.

In summary, NASA fulfills a unique role in its support of military aviation. It provides services for prototype development and testing and also provides consultation and basic knowledge derived from its excellent facilities and long-term fundamental studies. The NASA staff and facilities serve both military and civil interests, thereby getting maximum use from equipment and manpower.

Aeronautics is sometimes viewed as a mature field with few opportunities for major new advances. It is important to remember, however, that the swept wing, the jet engine, and pressurized fuselage appeared as practical developments in past years and that the rapid

development and application of these significant advances were not forecast. Some examples of innovative contributions by NASA research that were applied to military aircraft are listed in Table 5. NASA's role as a source of new aeronautical ideas must be stimulated in the future, if only to ensure that U.S. military power is not overmatched by unforeseen technological advances made abroad, perhaps by potential adversaries.

TABLE 5 Examples of NASA Technology Solutions Before Established Needs

Innovation	Military Application
All-Movable Tail Surfaces	F-86 and many since
Transonic Area Rule	F-102, B-58, and many since
Powered Lift Systems—Under-Wing and Over-Wing Blowing	AMST, CX
Variable Sweep Wings	F-111, F-14
V/STOL Thrust Vectoring in Flight	Harrier, AV-8
Supercritical Wings	AV-8B, AMST
Nozzle/Wing Interaction Lift Enhancement	AV-8B
Winglets for reduced drag and fuel savings	KC-135

NASA'S ROLE IN MILITARY AERONAUTICS: 1980 AND BEYOND

The diverse missions carried out by military aircraft have implications for a plethora of needs in aeronautical technology, now and in the future. Many of the military needs are closely related to civil needs in aviation, such as fuel economy, efficient structures, low-drag aerodynamic shapes, short take-off and landing capabilities, high-performance engines, and other features designed to provide low cost of operation and maintenance. Still other needs arise from specific military requirements, such as high maneuverability for fighter aircraft, launch durability, survivability against defenses, and hardening to blast and radiation. Needs that are not defense specific are supported in NASA by research groups with functional capabilities that enable them to make dual contributions to those ends and to those specifically related to defense.

Figure 1 is a matrix showing what the panel considers the proper role for NASA in support of DOD needs in aeronautical technology in several possible roles for various discipline areas. In making these judgments, the study panel considered such factors as flight performance and safety, fuel efficiency, environmental effects, manufacturing efficiency, economics, the "ilities" (i.e., those characteristics described under "Military Technology Needs"), and other specific military considerations. Use of NASA facilities may be required for the performance of any of the NASA roles; the "National Facilities" line in Figure 1 means that facility support is a dominant activity.

Based on an overall examination of the pattern of numbers on the matrix, the panel considers that Research, Generic Technology Evolution, and Facility Support in the fields of aerodynamics, structures and materials, and propulsion are the most important roles for NASA. The pattern indicates essentially no role for NASA in Prototype Development and Operations Feasibility for military aircraft and missiles, with some exceptions indicated by the superscripts and the special circumstances described in the footnote.

NASA ROLE CODE:
1. Major Role
*2. Moderate Role
*3. Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	PROPULSION	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE	1	1	2	3	2	2
RESEARCH	1	1	1	3[e]	3	2
GENERIC TECHNOLOGY EVOLUTION	1	1	1	3[e]	3	2
VEHICLE CLASS TECHNOLOGY EVOLUTION	2[a]	2	3[d]	3[e]	3	3
TECHNOLOGY DEMONSTRATION	2	2	3[d]	3[e]	–	3
TECHNOLOGY VALIDATION	2	3[c]	3[d]	3[e]	–	–
PROTOTYPE DEVELOPMENT	3[b]	–	–	–	–	–
OPERATIONS FEASIBILITY	–	–	–	–	–	–

NOTES:
(a) But Code '1' for airlift and V/STOL
(b) Extensive facility support
(c) But Code '2' for airlift and supersonic cruise
(d) But Code '2' for airlift, V/STOL, supersonic cruise, and fuel efficiency
(e) But Code '2' for flight and engine controls

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 1 MILITARY AERONAUTICS Role/Discipline Matrix

Although it is difficult to display in the matrix, NASA has the capability, to design, develop, and test experimental flight vehicles, because flight testing such vehicles is sometimes necessary for technology demonstration. NASA should undertake experimental flight tests in advance of established military requirements when the purpose is to provide advanced aeronautical data in regimes where potential applications may develop. Each such initiative will require consideration case by case.

Aerodynamics

By historical precedent, and because of its unique facilities and large complement of research personnel who are familiar with fluid mechanics, NASA has had a major role in aerodynamics for military as well as civil aircraft. While the industry has developed a strong capability in this area, NASA has the best capability in government. It stands to reason, then, that this role for NASA should receive continued emphasis in the future. Such work should proceed to the limits of available personnel to ensure that NASA has a major role

in Research and Generic Technology Evolution, as indicated in Figure 1.

In Vehicle Class Technology Evolution, NASA's role is subsidiary to the DOD research and development organization, with two exceptions: in the area of military transport and utility aircraft, NASA should play a primary role because these have much in common with their civil counterparts; also, NASA should continue to explore the technology for V/STOL until it is sufficiently developed to allow DOD applications.

As indicated by the chart, NASA should usually carry out supporting tasks for the DOD in aerodynamic Technology Demonstration and Validation. Finally, the development of military aircraft prototypes has been and should continue to be a DOD responsibility, though NASA plays an essential role in making available its expertise and facilities to support this activity.

Structures and Materials

NASA capability in structures and materials is significant and is used by the military services. Excellent NASA facilities are available for the development and testing of new materials and structural concepts, and important work is done in basic Research and Generic Technology Evolution.

The current work in advanced metallic and composite materials for aircraft structures should not only continue, it should be expanded. Improved materials and structures will benefit high-performance aircraft engine hot sections, as well as compressors and fan stages. Use of mode control for flexible structures in flight vehicles can provide such valuable payoffs as reduced structural weight, increased life, improved ride, and better flying qualities. Basic knowledge of flutter phenomena, dynamic loads, and fracture mechanics for current and new materials is necessary for advanced military air vehicles.

The DOD also has capable in-house laboratories as well as support from industry and universities. The DOD capabilities improve the application end of the role spectrum, and, therefore, they should play a major role.

Propulsion

In the field of propulsion, NASA's most important contribution is its capability to anticipate the need for the development of advanced propulsion technology when no formal requirement exists. This contribution is vital to ensuring that the technology is available when it is needed and that the DOD will have first-rate engines in the future. In general, key engine technologies are applicable for use in a wide range of military aircraft. NASA has, can, and should play a suitable role in supporting and establishing a base of knowledge in these technologies.

NASA should provide moderate support to the DOD in its National Facilities and Expertise role. Adequate facilities for testing large components and engines are available at other government locations, as well as at plants of major engine manufacturers. The know-how needed to operate such major facilities, with their modern instrumentation, recording equipment, and computational capabilities, also exists at other government and industry locations.

In the areas of Research and Generic Technology Evolution, NASA should continue its historic role in basic propulsion research. The basic research here should include compressor and turbine aerodynamics, combustion developments, digital electronic controls, life-prediction techniques on engine parts and structures, understanding of the properties of materials, the implications of alloying for the properties of such materials, as well as the use and limitations of composite materials in aircraft engines. The development of an understanding of basic phenomena does not receive sufficient attention in the private sector. The environment for research in NASA, in academe, and in certain industrial research laboratories is more suitable. NASA should be in a position to make a strong contribution in these roles.

The tasks related to Vehicle Class Technology Evolution, Technology Validation, and Prototype Development of new propulsion systems are best executed in industrial and military establishments through their normal working relationships. When NASA has unique capabilities, they should be used; otherwise, its contribution is properly in the "minor role" category.

Electronics and Avionics

This discipline logically divides into those electronics functions required for basic aircraft operation and those associated with mission accomplishment. More specifically:

Electronics

- Flight and engine controls; and
- Aircraft "overhead" functions, such as electrical power and life support.

Avionics

- Navigation and communication;
- Offensive and defensive avionics; and
- Weapons control.

Only flight and engine controls are intimately associated in the overall aircraft control system with aerodynamics, structures, and propulsion. NASA has a strong capability in this area and should

continue its support of the DOD. In all other areas of the total discipline, there is adequate capability in the military laboratories, in industry, and in universities. The panel sees no need for a significant expansion of NASA electronics and avionics capability in support of military aeronautical vehicles.

Vehicle Operations

For military aircraft operations, the principal contribution of NASA lies with its simulation facilities and expertise, which permit the simulation of operations such as shipboard V/STOL approach and landing, and air-to-air combat. The various military services properly consider the operational analysis, development, and refinement of military aircraft operations to be in the mainstream of their responsibilities and capabilities. Though NASA needs to be knowledgeable about military aircraft operations, it can receive most of the relevant information from the military.

Human Engineering

This discipline includes work on and use of simulators, crew work load studies, optimization of cockpit instrumentation and controls, and other items at the interface between the crew and aircraft. NASA has a major role in this area for civil aircraft, and the work is done mainly at Ames Research Center. NASA also stimulates and supports work in several universities.

Most basic NASA work supports DOD needs. This includes NASA flight simulations. Even so, NASA's work is paralleled by comparable efforts at the Air Force's Human Factors Research Laboratory and its Aeromedical Laboratory. Therefore, a secondary or supportive role is shown in the chart for Facilities and Expertise, Research, and Generic Technology Evolution in this area. NASA should not attempt to meet the DOD requirements in the more applied aspects of this discipline. These already are well covered by the DOD.

NASA/DOD Relationships

NASA and the military services have developed an array of effective working relationships, ranging from high level coordination of decisions on the one hand to daily technical interactions between working scientists and engineers on the other. An extensive number of joint or interdependent programs now exist, as shown in Table 6. Formalized review activities, such as the DOD/NASA Aeronautics and Astronautics Coordinating Board and the AFSC/NASA Interdependency Review Group, provide the basis for management decisions and formalized Memoranda of Understanding (MOU). MOUs for joint activities are negotiated at the laboratory/center management level in cases in which the program size and policy issues are within their purview (with visibility provided to higher management).

TABLE 6 Joint DOD/NASA Cooperative Programs in Aeronautical Research

Area	Number	Typical Examples
Air Force/NASA		
Propulsion	(27)	Full-scale engine research Controls technology Alternate fuels Variable Cycle Engine
Materials and Structures	(7)	Advanced composites T-38 tail Simulation Technology
Aircraft Research	(9)	Advanced Fighter Technology Integration program Highly Maneuverable Aircraft Technology program KC-135 Winglets
Missile Technology	(2)	Airlaunched strategic missiles
Other	(8)	Lightning transient effects
Navy/NASA	(8)	F-14 Aileron-Rudder Interconnect 2-Dimensional Nozzle Digital propulsion controls
Army/NASA	(4)*	Tilt Rotor Research Aircraft (XV-15) Rotor Systems Research Aircraft ABC™ (Advancing Blade Concept) Joint aeronautical technology at Ames, Lewis and Langley

*All Rotorcraft, but included for completeness.

Coordination and mutual understanding at the laboratory management and engineering level could be enhanced by an interchange of personnel and assignment of representatives to major laboratories or centers. The sharing of technical information, the conduct of experimental testing, and other joint activities are carried out directly between organizations at the working level and reported more formally to higher management.

ALTERNATIVES

The roles now performed by NASA in aeronautical technology theoretically could be done in various other organizational forms, if the United States were just beginning to organize its entire pattern for aeronautical technology activities. However, after 65 years of learning and team development among NACA/NASA, the military services, industry, and academe, any new management arrangement today would have significant disadvantages and few, if any, apparent compensating advantages. Carrying out all aeronautical technology activities within the DOD would require either some duplicate structure for civil aviation or the DOD would have to assume a civil aviation support responsibility. If the industry were to undertake this work, the balance between government and industry would be upset. It could lead to reducing competition among corporations and denying the government an existing capability for independent evaluation of industry effort. No advantage can be seen for merging aeronautical technology under another government department. Replacing NASA with a "not-for-profit" organization or a university in aeronautical technology offers no obvious advantage and carries the disadvantage of a major, time-consuming transition from the existing arrangement.

In summary, the existing role of NASA in support of military aeronautics is working well and is well coordinated. It needs only to be kept effective and then improved by increasing its responsiveness to changing military requirements and by the selective application of additional people and funding resources that should be made available to NASA.

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RECOMMENDATIONS

- As a matter of policy, the United States should reaffirm its historic commitment to preeminence in aeronautical technology as an essential element of a strong national defense.

- The existing role of NASA in support of military aeronautics is working well and should be strengthened.

- With specific regard to roles and disciplines in the matrix shown in Figure 1:
  - The role of NASA should be strengthened in the disciplines of aerodynamics, structures and materials, and propulsion. Military endorsement for this role should not be limited to currently defined needs, because perceptions of future needs are often misleading and inadequate.
  - The role of NASA in support of DOD should be a minor one in the disciplines of vehicle operations, human engineering, and those aspects of electronics and avionics which do not directly impact aerodynamic, structural, or propulsion design.

- The design, construction, and test of experimental aircraft to explore the frontiers of flight, even in the absence of apparent specific military applications, is a proper role for NASA. Such initiatives should be considered case by case for inclusion in the NASA program.

- The historical and currently excellent working arrangements between the DOD and NASA in aeronautics should be continued in program selection, management, technical cooperation, and data exchange.

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APPENDIX A

THE WHITE HOUSE

Washington

April 2, 1958

MEMORANDUM FOR: The Secretary of Defense
Chairman, The National Advisory Committee for Aeronautics

I have today transmitted to the Congress a special message recommending the establishment of a National Aeronautics and Space Agency. A draft of legislation carrying out this proposal is being transmitted to the Congress by the Director of the Bureau of the Budget.

The new Agency will be based on the present National Advisory Committee for Aeronautics and will continue that agency's well-established programs of aeronautical research. In addition, the new Agency will be responsible for programs concerned with problems of civil space flight, space science, and space technology. The instructions outlined below are concerned with these new activities.

The ultimate potentialities of space flight cannot now be fully grasped. Since some of these potentialities are clearly of significance from the standpoint of our national security, the Department of Defense will have a continuing interest in the programs to be undertaken and will continue to sponsor programs which may be peculiar to or primarily associated with military weapons systems or military operations as well as certain research and development which may be of a general supporting character. Furthermore, I desire that the skills and experience that have been developed within the Department of Defense be fully utilized in support of civil space programs. However, it is appropriate that a civilian agency of the Government take the lead in those activities related to space which extend beyond the responsibilities customarily considered to be those of a military organization.

I consider it especially felicitous that the National Advisory Committee for Aeronautics will provide the basic organization on which the new Agency will build. Not only does the National Advisory Committee for Aeronautics itself already have a firm understanding of the key problem areas involved and a tested method of approaching such

problems, but also this organization and the Department of Defense have long enjoyed a highly productive working relationship. This relationship will ease the period of transition that lies ahead and will provide a basis for the close cooperation that will be needed to solve the difficult problems that will be encountered. It is intended that the new Agency continue to perform for the Department services in support of military aeronautics and missiles programs of the type now performed by the National Advisory Committee for Aeronautics and also provide similar services with respect to military space programs; the Department, in turn, will provide support essential to the success of the new Agency.

In order that necessary work proceed without loss of momentum pending enactment of the proposed legislation, in order that interim measures may be consistent with the intent of this legislation, and in order that implementation of the legislation, when enacted, may be promptly initiated, I desire that the Department of Defense and the National Advisory Committee for Aeronautics take the following actions:

1. The National Advisory Committee for Aeronautics should prepare and present to the appropriate committees of the Congress a full explanation of the proposed legislation and its objectives.

2. The National Advisory Committee for Aeronautics should proceed to formulate such detailed plans as may be required to reorient its present programs, internal organization, and management structure to carry out the functions to be assigned to the National Aeronautics and Space Agency, including the functions now being performed by the National Advisory Committee for Aeronautics, and should also plan and propose such additional actions and programs as may be necessary to implement the proposed legislation. Such actions would include determination of any requirements for additional staff, facilities, or funds that may be needed in the immediate future.

3. The Department of Defense and the National Advisory Committee for Aeronautics should jointly review the pertinent programs currently under way within or planned by the Department, including those authorized by me on March 27, 1958, and should recommend to me as soon as possible which of these programs should be placed under the direction of the new Agency. The Department of Defense and the National Advisory Committee for Aeronautics should also prepare an operating plan to assure adequate arrangements for utilizing in support of the new Agency, either by cooperative arrangements or by transfer to the new Agency, appropriate organizations, facilities, and other functions now within the Department. These actions should be taken in the light of the fact that the proposed legislation contemplates that the new Agency will be given responsibility for all programs except those peculiar to or primarily associated with military weapons systems or military operations.

Supporting research and development should be coordinated to provide for the needs of both military and civil programs without unnecessary duplication. It should be noted that Public Law 85-325 authorized the Department of Defense for a period of one year to engage in advanced space projects designated by me. The one-year period will come to a close February 12, 1959. Since the new Agency will absorb the going organization of the National Advisory Commitee for Aeronautics, it should be capable of assuming direction of appropriate programs prior to that date.

4. The National Advisory Commitee for Aeronautics should discuss with the National Science Foundation and the National Academy of Sciences, as well as other governmental and non-governmental bodies, the matter of participation of the scientific community on a continuing basis in planning and coordinating the scientific programs for the use of space vehicles in civilian space science. The best scientific judgment available in determining space science objectives should be utilized. Matters related to dissemination of the data collected should also be considered.

5. The Department of Defense should identify and report to me what programs now appear to be needed in support of well-defined military requirements. It is understood that the Advanced Research Projects Agency will continue to serve as the focal point for such programs within the Department.

Any problems that may arise in carrying out these interim instructions should be discussed with my Special Assistant for Science and Technology or with the Bureau of the Budget, as appropriate.

DWIGHT D. EISENHOWER

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APPENDIX B

DEFINITIONS OF ROLES AND DISCIPLINES

To facilitate the task undertaken by the participants in the ASEB workshop, a series of definitions of possible roles for NASA was developed. The roles represent steps in the hierarchy of the research and development process, beginning with a desire for knowledge and an understanding of basic phenomena, an idea, or technical concept, and ending with the design and construction of a vehicle, a vehicle component, or a new operational system.

Definitions of Possible Roles for NASA

Each of the following eight roles as defined by NASA was reviewed by the participants, and the panels considered the extent to which NASA should carry out these roles.

National Facilities and Expertise

This category comprises the development and maintenance of test facilities, including wind tunnels, simulators, and computers, as well as the maintenance of personnel with specialized skills, technical knowledge, and expertise in the field of aeronautics.

Research

Programs in this category are designed to gain basic knowledge and understanding of physical phenomena and processes in all discipline areas relevant to aeronautics. The work is fundamental in character and is performed within NASA, at universities, in industry, and by independent research organizations.

Generic Technology Evolution

This category involves the pursuit of the results of specific lines of basic research that show promise of generating technology broadly applicable to a number of classes of vehicles. The work is evolutionary in nature and leads to the continued advancement of technology.

Such advances generally precede focused technology development in support of specific vehicle class needs. The work is conducted primarily within NASA, with appropriate university and industry support.

Vehicle Class Technology Evolution

NASA programs in this category concentrate on specific vehicle classes and on the preparation of the unique technology data base required to improve the design and development of certain classes of aircraft. Activities include generating and evaluating new concepts and configuration approaches for the vehicle classes. Examples include V/STOL and supersonic cruise vehicles. In both cases, the technologies unique to those classes of aircraft are examined with regard to design feasibility, benefits, costs, etc. Then tailored data bases are developed.

Technology Demonstration

This category includes programs that are conducted to demonstrate the technical feasibility of a technology advance or concept. Activities may include flight testing and component or systems demonstrations. Specific examples in the current NASA program are: Tilt-Rotor Research Aircraft, Energy Efficient Engine, Quiet Short-Haul Research Aircraft, and Terminal Configured Vehicle. Future modifications and tests on an aircraft to demonstrate the feasibility of Laminar Flow Control and flight tests of an Advanced Turboprop would be included in Technology Demonstration.

Technology Validation

This comprises programs that include large-scale ground or flight validation as a necessary step to assure technology transfer. The purpose is to make possible, with minimal risk and without additional technology development, the practical utilization of high-benefit, high-risk conceptual, component, or subsystem technology advances. Specific examples in the present NASA program are: Composite Primary Aircraft Structure (CPAS), Materials for Advanced Turbine Engine (MATE), and Engine Component Improvement (ECI).

Prototype Development

This category consists of design, development, construction, and testing of an aircraft, engine, or system that is sufficiently representative of a planned final product to serve as a production prototype. An example of such a program for the civil sector would be the supersonic transport (SST) program conducted by the FAA during the 1960s. Current NASA programs do not include any prototype developments, and none is currently planned.

Operations Feasibility

This refers to operations conducted as research directed toward evaluating the feasibility or practicality of aircraft system operations to meet special needs or requirements or to demonstrate that a total, integrated operational system (e.g., new aircraft or simulated new aircraft, advanced integrated flight systems, approach and landing techniques, wake vortex alleviation, etc.) provides a service or benefit. The economic, environmental, and/or social aspects are considered.

Definitions of Disciplines

Aerodynamics

Aerodynamics is the science dealing with the motion of air and other gases and with the effects of such motion on objects moving through such media.

Structures and Materials

This is the portion of aeronautical research and technology development dealing with the design of structures (the part of the aircraft, missiles and/or their components whose function is to carry loads in the broadest sense) and the materials used in aircraft and missile construction.

Propulsion

This disciplinary heading includes the part of aeronautical research and technology development relating to the various methods and systems for generating and delivering power for propelling and/or lifting aircraft and missiles.

Electronics and Avionics

Electronics refers to that aircraft and missile electrical equipment that is required for the basic operation of the vehicles--e.g., flight and engine controls. Avionics means the electrical equipment used for mission functions, such as air-to-ground communications and navigation. In military aircraft and missiles, the latter category includes offensive and defensive equipment and weapons control systems.

Vehicle Operations

This area deals directly with operational problems encountered by aircraft and missiles, such as icing, detection and dissemination of weather information, and air traffic control systems.

Human Engineering

This discipline addresses the study of human capabilities and problems that occur at the interfaces between the crew and the aircraft. It includes work on and use of simulators, crew workload studies, and studies of the optimization of cockpit instrumentation and controls.

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