A SURVEY OF SOME ELEMENTS IN AMERICAN TECHNOLOGY

by

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PREFACE

The purpose of this paper is to place American technology in some sort of historical perspective. This is admittedly a rather indistinct task, the results of which are not definitive in any sense. Numerous approaches could have been attempted, some of which would have been useful in this study. However, I chose the pattern employed here with the idea that it contained some of the more important considerations in the panorama of American technology.

Beginning with a discussion of the pronounced acceleration of technology in the last 150 years, we then proceed to a historical sketch of the role of the federal government vis-a-vis science. Finally, the Appendix contains brief outlines of several fields of technology which are relevant to today's advanced and sophisticated scientific developments.

C.M.B.

SUMMARY

A striking feature of the development of technology in the last hundred years is the tremendous acceleration which has been taking place. This acceleration is a characteristic of speed of travel and destructive power and is also evident in the multiplication of research tools and principles. Scientific and technological developments have had a prolific as well as a cumulative effect. Not only has more knowledge been added to the storehouse of technology, but all inventions spawn others.

One of the important considerations in a survey of American technology is the role of the federal government. The present close relationship between government and science has its historical roots in the early days of the nation. Though the consensus of the founding fathers was not in favor of government-sponsored science, the crises and growing pains of the nation have created our present government-science structure.

An examination of certain fields of technology indicates that the record is not one of steady progress. Many early innovations were ignored and experimental scientists were ridiculed. Americans have traditionally been more interested in utilitarian technology than in fundamental research, but there is some indication that more attention is being given to basic research and the development of new scientific principles.

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INTRODUCTION

During the twentieth century, the discovery of certain natural laws and the subsequent harnessing of natural forces have effected revolutionary results. Physics and biology, in particular, were transformed and greatly enlarged. Physicists gained an extraordinary knowledge of the nature of energy and matter. Biologists examined the infinite processes of living matter, ranging from microscopic viruses to man.

The development of machines of power and precision in technology kept pace with the advances in the basic sciences. A new era in transportation was ushered in with the invention of the internal combustion engine in the late nineteenth century and its perfection and practical development in the early twentieth century. Reliable and rapid transportation was realized in the automobile, airplane, tractor, truck, and armored military transportation. These, in turn, impelled the petroleum industry into a burgeoning feature of the American economy and society. Probably the most phenomenal growth in the transportation field was in aviation. In the United States, in 1950, 85 per cent of all passenger travel was by bus or train. In 1960, over half the passenger travel was by air.

The Soviet Union and the United States both exhibited a spurt in aviation and aeronautics after World War II. Supersonic planes and jet-propelled rockets were developed by both countries, with Soviet scientists emerging as the leaders in massive rocket construction. The first man-made earth satellite was launched by the Soviet Union in 1957, followed in 1959 by a missile which circled the moon, photographing its hidden side. In 1961, the Soviets launched the first successful manned orbital flight; the United States duplicated this feat in 1962. Several American satellites furnished information on weather, improved television and radio communication, and explored interplanetary space.

Formidable stockpiles of atomic bombs were built up by both the Soviet Union and the United States after the war; Great Britain also developed an impressive array of atomic weapons; and France, in 1960, began testing atomic bombs. Ballistics missiles, capable of traversing thousands of miles to an enemy target, were accumulated by the major world powers, and the United States pioneered in the construction of nuclear-powered submarines, which could launch rockets with atomic warheads from underwater.

The instruments of power and destruction were matched by instruments of precision which performed multitudinous services. Mechanical and electronic devices assumed complex functions which could be performed more efficiently and accurately than by human beings. Communications, transportation, and industrial systems, which have created and sustained great urban areas of the twentieth century, could not have operated without dial telephone exchanges, automatic meters, gauges, and pumps, gyropilots and numerous other objects of servo-mechanism.

New instruments played an undeniable role in peace and war. Radar searched the sky for hostile planes and was also highly useful in directing civil aviation during peacetime. Electronic calculators were designed to compute the speed and determine the target of guided missiles, while other instruments of similar construction were used to track the path and destination of hurricanes. The phenomenal development of science and technology has been one of the most influential and dynamic influences on twentieth century civilization, and a survey of the elements and trends in this development should be profitable in understanding the present American society.

ACCELERATION OF TECHNOLOGY

This essay will explore some of the factors in the acceleration of technology. It does not pretend to be complete or definitive but will examine in a general way the trends which are revealed in a study of this acceleration.

A recognition of the various fields in which acceleration has taken place reveals at least three outstanding areas: speed of travel, the mastery of physical power, and destructive power. There are indeed other aspects of technological development which could provide a helpful insight, but only these will be discussed.

In considering the acceleration of human speed it is interesting to note that the horse furnished the fastest transportation available from about 1700 B.C. when the Hyksos warriors invaded Egypt bringing horses with them until the invention of the locomotive in 1829. The use of wagons drawn by horses increased the utility of horse transportation but not the speed. The locomotive added new dimensions to transportation, and, in the period from 1829 to 1909, more speed was added to transportation than had been accomplished in the thousands of years of history and pre-history combined. The automobile became the fastest mode of transportation in 1910, and the airplane took the lead in 1920. From 1920-1960 automotive and aeronautical developments added about ten times as much to human speed as the locomotive had added in the eighty years from 1829-1909.

Another manifestation of man's mastery of the material world is revealed in his phenomenal exploitation and utilization of physical power. The primary source of energy throughout most of the history of mankind has been muscular energy. After man invented primitive tools, he gradually began adapting them to more efficient use. Handles were applied to stone hatchets; bows were employed to direct spears (or arrows) more successfully and also to multiply the muscular energy of the operator. But the source of the power was still muscular. Power reinforcement was furthered by the use of draft animals, beginning with ox-drawn wagons in the Tigris-Euphrates valleys around 3300 B.C. and horse-drawn plows in Egypt after the Hyksos invasion of 1700 B.C. This power was a striking improvement over human energy but was still muscular in origin.

The first extensive use of non-muscular power began with the Anglo-Saxons in their development of water-driven mills in the 700's A.D. The ancient Romans and Egyptians had employed water power to a degree but not on a wide scale. Windmills were developed in 833 A.D. in England, and there were certain minimal improvements in water mills and windmills during the Middle Ages. These were the main sources of power until the invention of the steam engine by James Watt in 1765. In comparison with the thousands of years of time during which man's use of power was muscular--either human or beast of burden--the duration of modern power sources of electricity, internal-combustion engines, and jet engines has been amazingly brief, a little more than a hundred years. Thus the rapidity of acceleration in mankind's mastery of the material world is clearly revealed in this dramatic upsurge in the physical power at his command.

The development of constructive power is closely matched by the awesome capabilities of a destructive nature invented by man. The acceleration of man's destructive power is demonstrated in several ways: the size of the area which can be destroyed, the accuracy of aiming devices, the number of tons which can be delivered to a certain target area, the destructive power per ton, and the speed or height of the projectile which enables it to evade interception. Military technology has multiplied so rapidly in the past century, and particularly in the last fifty years, that it is conceivable that within a decade or two all mankind could be exterminated. The fearsome trends that have been established are not based solely on the introduction of nuclear weapons but are the result of the steady acceleration of the power to destroy.

Turning now from the explicit fact that technological acceleration has taken place and a brief survey of selected fields of acceleration, it will perhaps be useful to examine some of the reasons for technological acceleration, with special attention given to the speedup of technology in the twentieth century. One of the basic reasons seems to be that the number of available tools has multiplied. The modern scientist has the chemical elements in purified form, chemical compounds, machines to supply almost limitless energy, and other valuable aids which are ready-to-use. Innovations in technology have a prolific as well as a cumulative effect. Not only is one more item added to the storehouse of technology, but each invention seems to spawn others. The invention of glass led to bottles and lenses which in turn gave birth to spectacles, magnifying glasses, telescopes, microscopes, range-finders, and searchlights. The number of elements available to combine into new inventions grows faster and faster.

Another significant factor in technological acceleration is the more rapid dissemination of new knowledge. Swift communications transcend tribal, state, and national barriers and thus speed technological development. There is a circular factor here in that technological innovations speed up communications, which then diffuse knowledge, which consequently makes possible more inventions.

A third reason for the speed-up of technology is that the means of defining the problems to be solved, gathering the elements to be joined, and working out the most efficient combinations of these elements, are all showing extraordinary improvement as our methods of invention become more and more scientific. Underlying principles are discovered which can lessen the necessity of testing useless combinations. Thus, acceleration of technology is heightened by improvements in statistics, logic, and the experimental process.

The last factor to be considered as a reason for technological innovation and consequent acceleration is the motivation of invention. The immediacy of the need which discoveries and inventions fulfill is not to be taken lightly. Reformers and inventors seem most likely to devote themselves to problems which intensely demand a solution. When an impelling need exists, the innovation will be adopted more readily and developed further. Motivation, however, is more significant in determining the relative speed of technology than the absolute speed. For example, the demand for a weapon with the destructive power of the atomic bomb would have been futile in the eighteenth century, since technology had not developed a capability for such a conceivable weapon. Yet, once the technology had approached an advanced stage, as it had in the United States in the early 1940's, the demand had significant influence on the development and construction of such a weapon.

In surveying the various aspects of the acceleration of technology and the reasons for it, there seems to be a pervasive tendency to accelerate; however, we must be wary of believing that progress is inevitable. An awareness of the phenomena of the rise and fall of empires warns against a blind faith in the inevitable progress of mankind and technology. In the first place, it seems evident that the acceleration of developments in science and technology has been primarily a characteristic of the Western world and has not been a force in countries such as India and China. Secondly, there is no guarantee that disasters and breakdowns, which have characterized societies and cultures of the past, might not vary in intensity, particularly in light of present destructive capabilities, and destroy the great bulk of modern culture and technology.

Many of the elements in technological acceleration have not been discussed here, and perhaps some of the more important ones have been omitted. An attempt has simply been made to illustrate some of the factors in acceleration. The rather ominous note sounded in several passages should not be over-exaggerated, but it reveals that a delicate balance prevails in the present state of technology. With renewed emphasis on the constructive and beneficial developments in technology, the equilibrium may be preserved and the destructive elements rendered less harmful.

THE FEDERAL GOVERNMENT AND SCIENCE

In a study of the development of American science and technology in the twentieth century, an understanding of the role of the federal government is essential. Though the present interest of the federal government in scientific and technological research is unparalleled in American history, there were significant events and trends throughout the nation's history which laid the foundation for today's relationship between science and government.[1]

During the constitutional convention in Philadelphia in 1787, the anticipated role of the federal government in regard to scientific development was hotly debated. Most of the delegates to the convention had scientific interests, in particular the unofficial "dean of American science," Benjamin Franklin. Charles Pinckney suggested a plan of giving the Congress the power to establish seminaries for study in the arts and sciences. James Madison proposed that Congress be empowered to institute a national university. Neither of these plans was accepted, due primarily to the objections of small-state delegations. The specific links between science and the federal government delineated in the Constitution were grants of authority over the census, patents, and weights and measures. The later policy of expanded government interest in science was justified by the general federal powers over regulation of interstate commerce, defense, and the general welfare.

The period before the Civil War saw little significant development in government-scientific relationships with the

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[1]The best work which traces the historical relationship between the federal government and science is by A. Hunter Dupree, Science in the Federal Government: A History of Policies and Activities to 1940 (Cambridge, Mass.: Belknap Press of Harvard University Press, 1957). Professor Dupree's book proved to be a very useful source for this study.

exception of the establishment of the Army Corps of Engineers in 1802, the Coast Survey in 1807 (later the Coast and Geodetic Survey), the Naval Observatory in 1842, and the Smithsonian Institution in 1846. During this time, however, science was becoming specialized, and, at the beginning of the Civil War, the federal government began utilizing scientific advice, the Navy being the primary employer of scientists. Congress founded the National Academy of Sciences in 1863 with the injunction that the Academy investigate various fields of science at the suggestion of the government. The federal victory in the Civil War firmly established the role of the government in scientific research. The states' rights obstacle, injected in the Philadelphia constitutional convention, was removed, and the federal government was free to inaugurate permanent scientific agencies.

The Department of Agriculture had its inception during the Civil War, receiving its initial legislative support from the enactment of the Homestead Act and the Morrill Act of 1862. The Homestead Act promoted interest in agriculture on the frontier, while the Morrill Act provided for the granting of public lands to the states for the establishment of agricultural and mechanical institutions.

The Hatch Act of 1887, which authorized federal assistance for experiment stations at land-grant colleges, gave added significance and responsibility to the Department of Agriculture. Thus, by the time the Department received cabinet status in 1889 it had already organized numerous bureaus which conducted research into specific agricultural problems.

The nation was becoming increasingly industrialized during the post Civil War period, and the natural tendency was for the federal government to exhibit the same interest in industrialization and its attendant problems as had been evidenced in agricultural research. Thus several important agencies were set up in the early twentieth century. In 1901 the National Bureau of Standards was established. Considerable scientific knowledge was utilized in effecting the regulatory practices of the Pure Food and Drug Act of 1906. This Act led inevitably to the inauguration of the Public Health Service in 1912. Increasing awareness of the potential of aviation urged the establishment of the National Advisory Committee for Aeronautics in 1915.

By the beginning of World War I scientists had proved their worth in the government and were being used in numerous agencies and departments. However, interest in science was limited to its immediate utility. Science was valuable in solving problems and formulating policy, but government scientists were discouraged from pursuing original research. The Smithsonian Institution was the sole government agency permitted to conduct basic scientific research, and it was handicapped by an extremely meager budget.

The beginning of World War I in Europe led to the setting up, in 1915, of the Naval Consulting Board, headed by Thomas Edison. The Board was divided into scientific committees in the various disciplines to consider the applications of science to military technology. Due to inadequate funds, it did not make a great contribution to the war effort and was used chiefly as a screening agency for inventions.

In the meantime, the National Research Council was instituted in 1916 as an offshoot of the National Academy of Sciences, which was suffering from enforced idleness. The mission of the Council was to coordinate the work of scientists in government and private laboratories. Although lethargic in the beginning, it began intensive activity in early 1918, and, with the cooperation of the Bureau of Standards, the Bureau of Mines, and scientific divisions in the armed forces, did extensive research, particularly in optics and gas warfare. The Council initiated close relations with numerous industries and secured assistance, to a limited degree, from university science personnel.

After World War I the research programs were largely dismantled, and there was very little progress in government-supported research during the 1920's. President Coolidge, an ardent exponent of laissez-faire economics, insisted that the government should not support scientific research. Funds for research for the armed forces were drastically slashed as well as appropriations for the National Research Council. The Council was made a permanent government agency, but was financially unable to conduct significant research. The only prominent public official who displayed any interest in aligning scientific research with the government was Herbert Hoover, and his efforts proved fruitless. The scientific establishment was thus confined largely to the colleges and universities.

However, a change was in the offing with the debilitating effects of the Great Depression. President Franklin Roosevelt understood the potential significance of government-sponsored research and instituted the Science Advisory Board in 1933. The Board was charged with investigating the use of science in government agencies and suggesting a plan for utilizing scientists who had lost their jobs in the depression. The Science Advisory Board suggested the establishment of the National Resources Committee in 1937 to study in greater detail the status of scientific and technological research in government, private industry, and educational institutions. The Committee issued its report, <u>Research--A National Resource</u>, which revealed the startling disparity among the scientific appropriations of universities, industries, and the government. The government devoted roughly two per cent of its annual budget for scientific research and development; the industries which were studied allocated an average of four per cent of their budgets to science; universities, however, devoted around twenty-five per cent of their annual budgets to research. Another significant finding presented in the 1937 report was that a distinct economic advantage accrued from the utilization of scientific research in the drug, electrical, metal, petroleum, chemical, and rubber industries. These economic benefits were analyzed thoroughly, and the report strongly suggested that sponsored research clearly effected certain discoveries which might stimulate the economy of the nation.

The economic condition of the nation in the late 1930's was none too optimistic, with economists making dire predictions about the long-run economic prospects of the nation. They reasoned that the nation was enmeshed in economic stagnation partly because the major technological innovations, such as the internal combustion engine and steam power, had already been exploited. There was a dearth of available investment opportunities. The report of the National Resources Committee held some hope for alleviating the chronic unemployment and invigorating the economy and advised that the government vigorously promote closer cooperation among government and science, both in an official way and at the lower echelons. The government should employ more scientists who would develop programs of research and development, as well as work with scientists in private industry and universities.[2]

The recommendations of the Committee were not immediately acted upon, and the 1939 federal budget appropriated only $50 million for all scientific research.[3] The advent of the Second World War, however, caused a revolutionary interest in scientific research and development. The National Defense Research Committee was set up by President Roosevelt in 1940 to conduct and coordinate research on war material. The Committee, unlike World War I's National Research Council, received generous government support. The Committee was composed of Chairman Vannevar Bush, president of the Carnegie Institution, the Commissioner of Patents, an admiral, an Army general, the Bell Telephone Laboratories president, two university scientists, and the presidents of the Massachusetts Institute of Technology and Harvard University. The Committee represented most of the established intellectual, governmental, and industrial institutions of the country. There was no time to create new organizations to initiate and conduct research and development. Cooperation among existing organizations was imperative if the scientific and technical needs of wartime were to be met. The Committee conducted research of its own interest and carried out specific research projects for the military as well.

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[2]U.S., National Resources Committee, Research--A National Resource (Washington, D.C.: Government Printing Office, 1938), I, 3.

[3]U.S., The President's Scientific Research Board, Science and Public Policy (Washington, D.C.: Government Printing Office, 1947), I, 10.

In 1941 President Roosevelt established the Office of Scientific Research and Development charged with pursuing scientific research and developing weapons production plans from research findings. The OSRD functioned as a clearinghouse for much of the research and development of the armed forces, the National Defense Research Committee, and the National Advisory Committee for Aeronautics. OSRD initiated the atomic energy research program and did much of the preliminary research before turning it over to the Army's Manhattan Project in 1943. The head of OSRD, Vannevar Bush, had ready access to the President, and science was of unparalleled importance in the conduct of national affairs. Numerous scientific advisory committees were set up by the National Defense Research Committee, the armed forces, and the National Advisory Committee for Aeronautics. As a result of the close cooperation among government and scientific institutions, the government began utilizing contracts not only to carry out specific research projects but also to set up entire research centers. Supported by government funds, these centers were administered by universities and industries. The government created a national research enterprise almost immediately with the establishment of such projects as the Los Alamos Laboratory at the University of California under the Department of the Army.[4]

The changes in the scientific establishment resulting from war mobilization were to have a permanent impact on postwar scientific research. Most of the nation's scientists had been associated in some way with government research and were anxious to secure more government help, particularly in basic research, since their work was now much more expensive and complex than ever before. Modern wind tunnels, nuclear accelerators, and other research tools were very expensive and completely beyond the reach of unsubsidized scientists.

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[4]Irvin Stewart, Organizing Scientific Research for War (Boston: Little, Brown and Co., 1948).

Vannevar Bush expressed to the President the thinking of many of the nation's scientists in his report, Science, The Endless Frontier, in July, 1945. He indicated the necessity for research for the advancement of medical science as well as for national security. In regard to the economic benefits for the nation from this new policy, Bush stated:

> One of our hopes is that after the war there will be full employment. To reach that goal the full creative and productive energies of the American people must be released. To create more jobs we must make new and better and cheaper products.... But new products and processes are not born full-grown. They are founded on new principles and new conceptions which in turn result from basic scientific research. Basic scientific research is scientific capital. Moreover we cannot any longer depend upon Europe as a major source of this scientific capital. Clearly, more and better scientific research is one essential to the achievement of our goal of full employment.[5]

Bush was stressing the very point which had been made so implicitly in the 1937 National Resource Committee's report, Research--A National Resource. The economic stultification of the depression had been erased by World War II, but the peacetime economy needed technological advancement which could come only from intensive research in basic science. Bush further advised that a government agency be established to encourage basic research and assist in the development of scientific manpower. The President's Scientific Research Board, under the chairmanship of John R. Steelman, heartily supported Bush's recommendations in its 1947 report, Science and Public Policy. This report suggested that the government subsidize

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[5]Vannevar Bush, Science, The Endless Frontier (Washington, D.C.: Government Printing Office, 1945), p. 2.

basic research in nonprofit institutions and universities to the amount of \$250 million by 1957, and that it spend at least one per cent of the gross national product on research and development.[6]

There was considerable wrangling and in-fighting among government agencies after the war about which agency should have primary jurisdiction over scientific research. Finally, the National Science Foundation emerged in 1950 as the organization to implement the recommendations of the Bush and Steelman reports for basic research support. After further debate over the relationship of the National Science Foundation to the executive branch, it was finally determined in 1950 that the President should appoint a director and a board of part-time scientists who were empowered to veto research grants. During the controversy over the administration of research, basic research was being conducted primarily by the Atomic Energy Commission; the National Institutes of Health, a division of the Public Health Service; and the Office of Naval Research.

Scientific research was thus firmly entrenched as a government interest by 1950, with the main concern being economic progress and the general welfare. The Korean War and the Cold War, however, turned the nation's attention once again to military-oriented research and development. Then the Soviet's _coup_ with Sputnik I in 1957 instigated further debate over the scientific establishment. Three important developments emerged from this debate: The Advanced Research Projects Agency was set up within the Defense Department to make military research more flexible; Congress created a new independent agency, the National Aeronautics and Space Administration, to conduct space research with civilian significance; and President Eisenhower appointed several eminent scientists to important advisory positions in the White House.

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[6]The President's Scientific Research Board, _op. cit._, I, 6.

Far greater expenditures for research have taken place than the Bush and Steelman reports foresaw. An examination of government research budgets reveals that defense-oriented research comprises the greatest share. Another significant characteristic of government-sponsored research is that most of the research and development is not performed within the government but is conducted by nonprofit institutions, universities, and private industries.[7] The old distinctions among education, government, and industry have been transformed into a partnership predicated on the national need of research.

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[7]See U.S., National Science Foundation, Federal Funds for Research, Development, and Other Scientific Activities (Washington, D.C.: Government Printing Office, 1963), XII.

APPENDIX

Abbreviated outlines and bibliography of important discoveries and developments in:

AVIATION--POWERED FLIGHT

EXPERIMENTAL PERIOD

Samuel P. Langley, Secretary of the Smithsonian Institution, built tandem-wing "Aerodrome," using very light engine, launched it from houseboat on Potomac, but it crashed due to inadequate wing lift and engine. Last experiment December 8, 1903.

Wright Brothers, Orville and Wilbur, after repeated efforts, made first powered, sustained, and controlled flights in history, Kitty Hawk, North Carolina, December 17, 1903.

TRIAL AND ERROR, 1903-1914

European Progress

Santos-Dumont made short flights (longest was 722 ft.) in plane with 50 horsepower motor and box wings at Bagatelle, France, 1906.

Wilbur Wright went to Europe in 1908, made over 100 flights and taught French how to control airplane in the air, also taught technique of propeller-making.

World's first air meeting, August 9, 1909, Reims, France--primarily light, rotary engine-powered biplanes.

Blériot on July 25, 1909, won competition in flying across English Channel from Calais to Dover--forcibly impressed on public mind potential of airplane.

United States Progress

Aerial Experiment Association made its first flight March, 1908, the "Red Wing."

Glenn Curtiss's "June Bug" won Scientific American prize in July, 1908, for first flight over a kilometer in U.S.

Eugene Ely in Curtiss biplane made first successful take-off from a ship, U.S.S. Birmingham, November, 1910.

Glenn Curtiss won first Collier trophy 1911, for first practical float plane.

Developments from 1912-1914--still trial and error, each plane a separate invention. Construction changes--development of steel fuselage and streamlining. Military personnel--interested but only for reconnaissance purposes. Glenn Curtiss built three-engine flying boat in 1914 to fly Atlantic but outbreak of war prevented it.

PRACTICAL DEVELOPMENT, 1914-1940

Aviation During World War I

By outbreak of war all combatants had a few trained pilots and flyable craft.

By end of war most had sturdy planes, engaged in aerial combat at low altitudes and carried bombs.

U.S. had no air force at beginning of war in 1914. Produced hundreds of Curtiss training planes but no American fighting planes saw action during war.

Transatlantic Flights, 1919-1930

British officers Alcock and Brown flew nonstop from St. John's, Newfoundland, to Clifden, Ireland, June, 1919--twin-engined Vickers Vimy biplane bomber.

Charles A. Lindbergh flew first nonstop flight from New York to Paris, May 20-21, 1927, in "Spirit of St. Louis"--3600 mi. in 33 hours, 39 min.

German Junkers monoplane "Bremen"--first nonstop flight from east to west, Ireland to Newfoundland, April, 1928.

Frenchmen Dieudonne Costes and Joseph Le Brix--first south Atlantic crossing, October 14-15, 1927, Senegal to Rio de Janeiro.

Costes and Maurice Bellonte--first nonstop Paris to New York flight, September, 1930.

Transpacific Flights, 1927

L. J. Maitland and Albert Hegenberger flew Fokker monoplane from California to Hawaii, June, 1927.

Flying contest from Oakland, California, to Hawaii, summer, 1927--only two of eight reached Hawaii.

Exploration Flights, 1920-1929

Africa was crossed, 1920.

Admiral Richard Byrd and Floyd Bennett made round-trip flight to North Pole, May 8-9, 1926.

Byrd circled South Pole, November 9, 1929, in Ford trimotor "Floyd Bennett."

First round-the-world flight by U.S. Army Douglas biplanes, 175 days, April-September, 1924, bases had been set up in numerous countries.

Scientific Research and Development

Engines began changing from liquid cooling to air cooling in 1927.

Airplane construction--engine was housed in cowling, also retractable landing gear, early 1930's.

Wind tunnel studies indicated new shape for wings and other surfaces--1930's.

Round-the-World Flights

Wiley Post and Harold Gatty--15,474 miles in 8 days, 16 hours, June, 1931, first fast round-the-world flight.

Post few round-the-world--7 days, 19 hours, July, 1933.

Howard Hughes--round-the-world in twin-engined Lockheed, 3 days, 19 hours, 1938.

Air Transportation

Boeing 247 in 1933 and Douglas DC series in 1934 represented significant developments: (1) all metal construction, cowled engines and retractable landing gear; (2) large and relatively soundproof; (3) carried electronic navigation and communication equipment for worst weather conditions.

<u>Four-engined planes</u> used extensively in 1930's--prototype of long-range military transport planes of World War II.

<u>Water-based aircraft</u> developed early 1930's; by mid-30's French were making regular transoceanic trips in Latecoere flying boats. <u>Pan-Am</u> began using huge Boeing flying clipper ships <u>1935</u>, but land-based planes had more advantages, especially with increased reliability of aircraft and communications.

<u>Private flying</u>, because of depression, did not really develop until <u>1937</u> and cost was still prohibitive.

<u>Helicopters</u> not developed to great utility until <u>1940</u>, though flown successfully in 1922; was used in war by both sides but not of great significance until Korean War.

<u>Rigid airships</u> (blimps)--interest grew after World War I, proved useful but were vulnerable to adverse weather; interest dropped almost entirely after <u>1935</u> with several unfortunate U.S. experiences.

ACCELERATED DEVELOPMENT, 1940-1960

Jet Aircraft, 1939-1945

<u>Englishman Frank Whittle</u> received first patent on jet-propelled aircraft, <u>1930</u>.

<u>First jet flight</u>--German Heinkel He 178, <u>August 27, 1939</u>.

<u>First American jet flight</u>--Bell XF-59A, using two I-16 GE turbojet engines (Whittle's design), Muroc Dry Lake, California, <u>October 1, 1942</u>.

<u>By end of war in 1945</u> Germans had 1300 Messerschmitt Me 262 twin jets and British had Gloster F-9-40 Meteor in full production. Neither affected outcome of war but ushered in new design.

Air Power in World War II

Germany tried to vanquish Britain by air bombardment in late 1940, but Britain successfully defended itself with fighter planes aided by radar.

British and American air force bombed German industrial centers around the clock 1943-1945.

Carrier-borne American naval aircraft helped U.S. drive across Pacific.

U.S. bombers from Mariannas destroyed Japanese industries, ended war by atomic bombing of Hiroshima and Nagasaki, August, 1945.

Between December, 1942-January, 1944 U.S. produced 29,000 bombers; 39,000 fighters; 7,000 transports; 20,000 trainers. Produced 96,318 aircraft in 1944 alone.

After World War II aviation industry disrupted when government stopped placing orders. But companies began working on design based around jets.

Air Power in Korean War, 1950-1953

Jet used--aerial combat--first time--U.S. Sabrejets and Soviet MIG 15's. Jets also used--low-level ground attacks since conventional aircraft too vulnerable to anti-aircraft. Helicopter came into its own--rescued downed pilots, transported personnel to front lines, carried wounded to hospital.

Postwar Aviation

Domestic route mileage increased 3½ times 1946-1948.

Britain had lead in jet-powered transports beginning 1952 with Havilland Comet and turbo-prop Viscount but serious accident grounded them from 1954 to 1959.

U.S. took over most long-range transport in 1959 with Boeing 707 jet transport, then Douglas DC-8 and Convair 880.

Airlifts. Berlin airlift 1948-1949--food and fuel. Operation "Magic Carpet" 1952, Lebanese Muslims--carried to Mecca. Food and fuel dropped--devastated areas.

International regulation of airlines--two permanent bodies organized--International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA).

Military aircraft. Revolutionary change--appearance and performance. U.S.-built X-1 attained supersonic flight, October, 1947. By 1949 U.S. Strategic Air Command had Convair B-36D (6 conventional and 4 jet engines)--joined in early 1950's by 6-engined swept-wing B-47 jet. In mid-1950's Boeing B-52 jet; core of U.S. bomber planes by 1961.

Aviation Research--some unsolved problems, primarily safety; most research was oriented to space flights. By mid-1950's--speeds into supersonic range. North American X-15, rocket-powered airplane reached Mach 3 in 1960 and over 4000 mph on November 9, 1961. Designed primarily for shallow penetration of outer space but also information on high speed flight.

Remaining problems--vertical take-off and landing (VTOL) and stationary take-off and landing (STOL). Control of air traffic near airports. Worst aviation disaster in history, December 16, 1960--jet airliner collided with prop plane over New York City, killed 134 persons.

RADIO

BASIC DISCOVERIES

James C. Maxwell, a Cambridge physicist, predicted 1865 existence of radio waves--purely deductive, based on scant knowledge of electricity.

Heinrich Rudolph Hertz experimentally proved Maxwell's theory, 1885. At same time he discovered photoelectricity. Also produced electric waves and examined their nature, 1887-1888.

Edouard Branly invented interceptor, 1890.

TELEGRAPHY

Guglielmi Marconi was first to combine Hertz source of electric waves with Branly interceptor. Sent dots and dashes one mile (wireless) 1895; 74 miles 1898; 200 miles 1900; 2000 miles (from Cornwall, England, to St. John's, Newfoundland) December 12, 1901. Knowledge was limited--physical basis of electrical waves was understood but little known about laws of propagation to a distance. Knowledge of electrons very limited.

PRIMITIVE RADIO

First radio broadcast (really wireless telephony) by Reginald Fessenden, December, 1906, Brant Rock, Massachusetts. Employed heterodyne reception, used arc generator.

Lee De Forest invented audion tube 1907. Was 3-electrode vacuum tube, had detector and amplifier--useful in wireless telegraphy and telephony, used as generator and detector. Supervised installation of radiotelephony on 20 U.S. Naval vessels, 1909. Made first commercial experimental broadcast from Eiffel Tower, Paris,1910.

Ernst F. W. Alexanderson improved Fessenden's alternator, 1909. Developed multiple tuned antenna, 1913--was multistage radio frequency magnetic amplifier, greatly increased amplification.

Edwin H. Armstrong developed feed back system, 1914--a regenerative circuit, produced tremendous amplification and helped eliminate squeal due to continuous oscillation. Developed superheterodyne, 1915--shortened antennae and made receivers more sensitive and selective.

RADIO CAPTURES PUBLIC IMAGINATION, 1910-1915

Radio engineering introduced. Dr. Michael I. Pupin, one of leaders, made many contributions to radio science.

Radio International Conference--first meeting, London, 1912--to promote uniformity of wireless operators.

American Institute of Radio Engineers organized, 1914.

John Wanamaker Company installed wireless between New York and Philadelphia stores, 1914--David Sarnoff in charge.

First transatlantic radio broadcast, 1915.

WARTIME USES--WORLD WAR I

Radio most effective with ships at sea and with airplanes. Vacuum tube improved and widely applied in sending and receiving apparatus.

COMMERCIAL BROADCASTING

After World War I numerous radio technicians returned and instigated for widespread commercial broadcasting.

RCA organized--1919; took over Marconi Wireless Company.

KDKA--first commercial broadcasting station, 1920--Pittsburgh. Developed by Westinghouse Company and Dr. Frank Conrad. Broadcast results of Harding-Cox election.

Increase of stations. By end of 1922--30 licensed stations. 1924--500 stations. Multiple station networks began 1924. NBC organized--1926. Round-the-world broadcasting accomplished--1930.

Receiving sets. Superheterodyne could have eliminated squealing and lack of amplification in crystal sets but too complicated to tune. Neutrodyne receiver developed by Dr. Frank Hazeltine, 1923. Permitted reception of wide band of frequencies at fixed position on dial.

Alexanderson's electronic amplifier replaced magnetic amplifier--late 1920's. Stepped up power tremendously, became basic principle of modern broadcasting transmitter.

FM Broadcasting. Alexanderson perfected frequency modulation, 1933. It overcame natural and manmade static. Alexanderson worked single-handedly. Major broadcasting stations not interested. Obtained backing in small independent New England stations where static was bad. Slow to catch on--by 1940 only 150 applications for FM broadcasting licenses. Still slow but growing steadily. Reason for lack of popularity--probably economic considerations of radio stations (would be interesting study).

Short wave broadcasting. Useful in long-distance broadcasting, freer from static. NBC and CBS experimented with short wave--1930 but discarded it. During World War II, U.S. government took over short wave stations. By 1945, 36 government transmitters were broadcasting round-the-clock. Long wave AM commercial stations use short wave for point-to-point communications and in national hookups.

RECENT TECHNOLOGICAL DEVELOPMENTS

Bell Telephone Laboratories developed transistor, 1948.

Atomic-powered batteries developed for use in portable radios.

First radio talks with man in space, Russian cosmonaut Yuri Gagarin, 1961.

RADAR

BASIC DISCOVERIES

See "Basic Discoveries" under "Radio."

Karl Ferdinand Braun invented cathode-ray oscilloscope, 1897.

Nikola Tesla, Hungarian-born American scientist, stated in 1900 that with radio detection ships could be detected and located.

Christian Hulsmeyer developed simple radio echo device to prevent ship collisions, 1904--very little interest in it.

Albert H. Taylor and Leo C. Young (U.S. Naval scientists) were studying short wave radio and detected radio echo reflections from boat on Potomac River, 1922.

PRACTICAL DEVELOPMENTS IN U.S.

Gregory Breit and Merle Tuve used radio pulse principle to measure ionosphere, Washington, D.C., 1925. This was adopted by ionospheric investigators all over the world.

Leo C. Young and L. A. Hyland observed radio reflections from aircraft, 1930. Used system of continuous radio waves called "beat" method, did not give range, only detected aircraft 50 miles away. Young proposed using pulses of radio waves, 1934--beginning of modern radar.

U.S. Naval research. R. M. Page developed radar using Young's suggestion and observed echoes from aircraft, December, 1934. Pulse radar with range detector (up to 25 miles) developed, early 1936. Pulse radar tracked small aircraft 100 miles away, 1938. Navy installed models of this radar on 20 major warships before Japanese attacked Pearl Harbor, December 7, 1941. In 1936 navy scientists showed their equipment to Army Signal Corps and electronics engineers. Signal Corps had been working secretly on radar and demonstrated pulse radar shortly after Navy did. Army had two good radars ready by 1941. Army radar unit detected Japanese air fleet nearing Pearl Harbor but thought they were American bombers.

BRITISH DEVELOPMENTS

Robert Watson-Watt developed pulse radar capable of detecting aircraft up to 17 miles away, February 26, 1935.

By late 1935 main features of chain of warning systems were worked out. By early 1938 first five stations of chain completed. Many more were built in later years.

Interest then shifted to air-borne radar equipment. Not much success until invention of multicavity magnetron (10 kw of pulse power), 1940. Made microwave radar practical. For sharp radar beams either very large antennae or very short radio wave lengths were necessary. Large antennae impractical for airplane. Magnetron solved problem.

FRENCH DEVELOPMENTS

Installed beat type collision-warning radar on liner "Normandie," 1936.

Developed pulse radar by 1940.

GERMAN DEVELOPMENTS

Began working on radar--1935; had good wartime radar for early warning, anti-aircraft gun control, and for ships. Did not develop microwave radar and failed to obtain accuracy of Allies.

OTHER COUNTRIES

Russia and Japan had radar warning system by 1941 and 1942 respectively.

No other country had as good radar or used it as extensively and effectively as U.S. and Britain.

DEVELOPMENT AND USE OF RADAR IN WORLD WAR II

U.S. and Great Britain cooperated closely. Great Britain gave U.S. multicavity magnetron and U.S. gave Great Britain duplexer switch.

Microwaves developed narrow-beamed, highly accurate radars with small antennae for aircraft, ships, and mobile ground stations.

Wartime cooperation of Allies marked beginning of modern university-government-private industry cooperation. Much of American work done at M.I.T. Radiation Laboratory.

Radar had become so effective by 1942 in aiming anti-aircraft guns that each side tried to jam the other's radar with radios and tons of aluminum foil strips to reflect false echoes on enemy's indicators. Allies' superior radar could overcome jamming. Axis powers' radar could not.

Germany did nothing about microwave radar until 1943 and war was over before they could develop it. Hitler had ordered big cutback in research--1940. Very poor cooperation among military and civilian scientists.

Ocean warfare. In Pacific radar gave U.S. Navy superiority over Japanese in night naval battles. In Atlantic airborne radar enabled Allies to inflict crippling losses on German submarine fleet.

POSTWAR U.S. DEVELOPMENTS

MADRE--late 1950's--to "see" over horizon. Uses radar waves with frequencies similar to short waves. Range--800 to 2000 miles; can detect low-flying objects.

DEW line (Distant early warning)--far north of North America and Texas Towers up to 200 miles out in Atlantic.

BMEWS (Ballistics missile early warning system) began October, 1960, in Thule, Greenland. Detects missiles 3000 miles distant.

Military developed mapping radar in late 1950's.

Civilian developments. Some airplanes have radar navigational equipment but not all. Radar astronomy much more accurate than optical astronomy; first radar contact with moon, January, 1946. Simple radar for coastwise navigation.

TELEVISION

EXPERIMENTAL PERIOD, 1876-1925

Sir William Crookes discovered cathode rays, 1876.

Paul Nipkow, a German, invented mechanical scanning disc, 1884. Worked on principle of persistence of vision.

With commercial application of telephone many were interested in wired-image transmission as well; by 1909 interest had waned.

PRACTICAL APPLICATIONS

Charles Francis Jenkins sent picture of President Harding by telegraph from Washington to Philadelphia, 1923. Used system of prisms for scanning instead of Nipkow's disc, but was same principle as Nipkow's.

Herbert Eugene Ives (with Bell Telephone Laboratories) showed President Hoover on large neon tube as he was broadcasting several hundred miles away--used wire transmission.

Vladimir Zworykin, Russian-born American citizen, developed iconoscope, 1923.

Philo Taylor Farnsworth invented electronic scanner, 1927; called it "image dissector." It replaced mechanical scanner and produced several stages of amplification.

COMMERCIAL APPLICATIONS, 1930-1958

RCA built first transmitting station atop Empire State Building, 1935, and began its TV research program.

Allen B. Dumont further developed kinescope tubes, late 1930's; greatly improved clarity of pictures. He marketed first modern home TV receiver, 1939.

New York World's Fair, April 30, 1939, President Roosevelt inaugurated public TV by RCA and NBC.

By 1940 several other similar systems were ready for commercial operation, but FCC delayed approval until a uniform nationwide system could be agreed upon. Standardization settled by 1941, and full-scale commercial operation was authorized, but World War II intervened. CBS and NBC maintained TV broadcasting during war but on very limited scale.

POSTWAR DEVELOPMENTS

Began first rapid expansion into mass communications medium, 1948.

Freeze on new station applications, 1948-1952, to standardize channels. In 1952 new boom with authorization of UHF.

First transcontinental TV network begun, 1951.

Color television. Earlier mechanical dissectors rejected by FCC and electronic version approved--1953.

1958--about 600 stations, 46,000,000 TV sets. Three major systems: NBC, CBS, ABC. A fourth, Dumont Television Network, withdrew--1955--unable to get channels.

ROCKETRY

DEVELOPMENT OF FUNDAMENTAL PRINCIPLES

Konstantin E. Ziolkovsky, Russian schoolteacher, first considered applying rocket's action to escape earth's atmosphere--"Investigation of Cosmic Space by Reactive Machines"--1903.

Robert H. Goddard developed anti-tank rocket, forerunner of "Bazooka" for U.S. Army, Aberdeen Proving Ground, Maryland, November 10, 1918. In 1919 published "A Method of Reaching Extreme Altitudes"; dealt with use of rocket-powered vehicles to send scientific instruments into and beyond stratosphere. Speculated that it might be possible to put instruments on moon with very large rockets; was ridiculed by newspapers.

Herman Oberth, German scientist, published first complete mathematical dissertation on mechanics of flight beyond atmosphere via rockets, "The Rocket into Interplanetary Space"--1923. Aroused rocket research in Europe during 1920's.

GODDARD'S DEVELOPMENTS

Fired first liquid-propellant rocket near Auburn, Massachusetts, March 16, 1926, traveled 184 ft. in 2½ seconds. A milestone but fire marshals banned further experiments. Colonel Charles A. Lindbergh got grant from Guggenheim Foundation for Goddard to move to Roswell, New Mexico, where he continued research.

Fired 11 ft. rocket carrying small camera, thermometer, and barometer--recovered intact, 1929, Roswell, New Mexico.

Fired 11 ft. liquid fuel rocket to height of 2000 ft. at 500 mph, 1930, near Roswell, New Mexico.

First flight of rocket with gyroscopically-controlled vanes for stabilized flight, April, 1932, Roswell, New Mexico.

First rocket using gyroscope to control steering mechanism. Went 4800 ft. high, flew 13000 ft. at 550 mph, March 28, 1935.

OTHER AMERICAN DEVELOPMENTS

American Rocket Society--first to pass sonic barrier--700 mph, September 9, 1934.

National Academy of Sciences sponsored first U.S. rocket program; began research for development of rockets suitable to assist air force planes on take-off, 1939.

GERMAN DEVELOPMENTS BEFORE WORLD WAR II

Eugene Sanger, Austrian scientist, conducted many experiments in 1930's, working on plans for rocket-powered airplane.

Peenemünde began May 1937, German rocket experiment station; worked on V-1, V-2.

ROCKETRY DURING WORLD WAR II

United States--first U.S. rocket gun, "Bazooka" was standardized, 1942.

Germans fired first successful experimental V-2, a long-range rocket, October 3, 1942. Began firing V-2's against Sarnacki, Poland, May, 1943. Fired first V-1 (pilotless pulse-jet winged aircraft) on London June 13, 1944; had warhead of 1,988 lb., range--190 miles. First V-2 on London, September, 1944--3400 mph.

POSTWAR HIGH ALTITUDE ROCKETS--U.S.

V-2 rose 114 mi. above White Sands, New Mexico, December 14, 1946.

"WAC Corporal"--first high-altitude sounding rocket, 1947, not large enough to carry instruments.

"Viking"--U.S. Navy large liquid fueled--1948. Carried instruments into upper atmosphere, examined solar radiation above atmosphere and photographed earth from high altitudes.

First two-stage rocket. Small "WAC Corporal" set in nose of V-2 and fired when V-2 reached 20 mile altitude. Rose to 250 miles, 500 mph. U.S. Army, February, 1949.

First supersonic flight by man--Bell Aircraft Corporation's X-1, a rocket-powered airplane, flown by Charles Yeager, October 14, 1·47. Was carried 35,000 ft. up by bomber and then released--had 8000 lb. of fuel, burned for 3-4 minutes.

First rocket motor plane--Douglas "Skyrocket," flown 1951.

Rocket-powered X-15, by North American Aviation, was developed to practical stage, 1960.

Space age began--first satellite, Sputnik I--October 4, 1957, launched with 3-stage rocket.

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