UNCLASSIFIED

US Air Force Historical Study No. 20

COMPARATIVE HISTORY OF RESEARCH AND DEVELOPMENT POLICIES AFFECTING AIR MATIERIEL 1915-1944

PREPARED

Prepared by AAF Historical Office Headquarters, Army Air Forces June 1945

SCANNED BY ISA

THIS PAGE Declassified IAW EO12958
Comparative History of Research and Development

Policies Affecting Air Materiel, 1915-1944

Prepared for
Scientific Advisory Group
Office of the Chief of Air Staff

Prepared by
Historical Division—Assistant Chief of Air Staff, Intelligence
June 1945
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The statement that "during the period 1918-1939 no new weapon was developed by or for the Armed Forces" is not borne out by the facts unless one insists upon the narrowest interpretation of the word "new."

Virtually each of the 100 or more tactical airplane models developed by or for the Army's Air Arm between 1918 and 1939 might be regarded as new in the sense of having a new performance, a new range, a new speed, a new altitude, or a new size power or striking power in comparison with its predecessors. The differences between the Martin bomber of 1918 and the Boeing XB-15 and Y1B-17A of 1939 are too vast not to label the latter articles as new by contrast. Likewise the power plants, the armament, and the electronics equipment installed in the combat airplanes in 1939 bore little resemblance to those in use at the end of World War I. Likewise the standard engines, propellers, beabsights, turrets, and radio equipment of 1939 had little in common, in terms of performance, with their lineal ancestors of 1918. (pp. 32-38). Some of them were gradual evolutions, while others were radical departures from 1918. Still other radical departures were the following projects which had been explored experimentally by 1939: an aircraft warning system, built in 1937 by the Signal Corps (p. 37); radio-controlled missiles, tested at various times between 1918 and 1935 (pp. 37-38); and jet and rocket propulsion, being studied under an Air Corps contract since December 1938 (p. 38).

How many of these aeronautical frontiers of 1939 were "new" if compared with the progress among the various foreign air forces is another matter. By 1939 Italy had apparently already achieved working models of a jet-propelled plane (pp. 164-166); whereas America had not quite reached this stage. England's "radio locater" was probably more advanced in 1939 than was America's aircraft warning system. (p. 37). And many (but not all) of Europe's best combat planes, while they were not all in effective production, were superior to some of the best experimental models of the Air Corps (p. 34).

How effective the AAF has been over the last 30 years in translating scientific ideas into better weapons, and whether other countries have excelled in solving any of the various phases of this problem is the subject of the attached seven studies. In some ways there
are more similarities than differences. The research and development systems of the various military establishments throughout the world have had as many aspects in common as aspects that were dissimilar or unique. Thus, the whole body of procedures loosely called "the scientific method" is something that after all has no national boundaries. Next, the system of "military requirements" is an essential component of all air forces, whether organized into a division by that name, an air staff office, a committee system, etc. Closely related to requirements in research planning: the Air Corps had its 5-year program in 1939 (pp. 39-40), and its 5-year postwar program in 1945 (p. 92); so also with Germany and the Soviet Union in other years (pp. 144, 150). Other problems are also universal and international: budgets, scientific personnel, the construction of laboratory facilities, and research contracts with industry and universities all represent problems that under different names have been common to autocratic and democratic nations alike, and common to World War I, World War II, and the years of peace in between; common in the sense that conflicting demands and priorities arose that reflected conflicts between development of the new standardization of the old; between demands for quality and demands for quantity; between one field and another (for example, aerodynamics vs. electronics, and internal-combustion power vs. jet propulsion), and between military plans and civilian sources of scientific research.

National attitudes

American appreciation for scientific research has probably been more vocal in the fields of the "practical" sciences than in "fundamental" or "pure science," difficult as it is to dissociate them. Edison, Ford, and Kettering are all well-known names in the last 30 years of American history; scientific "symbolism" and laboratory stereotypes have been common advertising copy for a generation of more in the popular magazines; and the public has shown a normal interest in the Wright brothers, in the historical museum at Wright Field, and the wind tunnels at Langley Field. Much of this interest stems from a spontaneous curiosity of Americans toward new mechanical devices, but it has also been cultivated and inspired by planned programs of public relations--by commercial publicity for laboratory-developed consumer goods and by Army publicity in behalf of its experimental activities (pp. 41-42, 54-55). The generous release to the public of information on secret wartime aeronautical developments long before the German collapse in May 1945 is both a cause and an effect of this public interest in the gadgets of war. In other countries "popular science" has not been as vigorously cultivated except, perhaps, in the Soviet Union, where scientific accomplishments have been front-page news in the government-controlled press for a decade.
or more (p. 151). The controlled press among the Axis powers, on the other hand, did not neglect scientific matters in its propaganda and information programs, especially where they were connected with problems of national self-sufficiency and military preparedness. Of these powers, Germany had inherited the most consistent scientific tradition, an inheritance which even the Nazi government did not alter appreciably (pp. 132-134). But whether it was shared by the general public is debatable. Germany's historical attitude toward science, an interest in the theoretical foundations of applied science, was probably less a broad "popular" enthusiasm than an intellectual attitude shared by the small scientific elite of that country.

More important for aeronautical advancement than popular support of science has been popular support of military preparedness. In the United States, the prevalent indifference toward national preparedness before 1916 and from 1920 to 1939 is well known (pp. 22, 30-31, 47, 48, 55). This indifference, variously explained in terms of pacifism, isolationism, and a preoccupation alternately with prosperity and depression, certainly had an adverse effect on scientific progress in military aeronautics, in spite of the fact that Army aviation after 1914 usually had a better press than other components of the armed forces. In other countries, meanwhile, public support for military preparedness and expansion was usually at a higher pitch, but it varied with national aspirations. Military programs were revived in Italy in 1925, in Japan in 1931 (or earlier), and in Hitler's Germany in 1933, and the popular consciousness and enthusiasm developed in those countries was usually carried over to military aeronautics as well (pp. 151, 85, 138, 174). French and British sentiment for military aviation began to increase about 1936, but American opinion was not to become consistently favorable until 1939 and 1940 (pp. 174, 99).

National attitudes in the Axis countries were more consciously cultivated and planned by the controlled press, but even in democratic nations the articulate public opinion was hardly spontaneous. It would appear that in all countries—regardless of their political or economic structure—the governments have found it necessary to defend their programs for war research by means of propaganda, publicity, and public education: in Germany, Italy, and Japan in terms of national self-sufficiency and national superiority (pp. 138, 134, 183); in other European countries in terms of national defense; and in America, in terms both of preparedness and of the peacetime application of wartime developments. The Kilgore Committee's recent list of some 1, 400
technological accomplishments in World War II has been publicised not only as a tribute to America's wartime progress but also as a guide for the conversion of her "swords" back to "plowshares."

Aside from public opinion in the aggregate were the attitudes of scientists and their managers, whether in industry or in other institutions. German industry and science in the early twentieth century were grounded in a superb tradition of "theoretical" science (p. 132), while American laboratories by the 1930's surpassed the rest of the world in their emphasis on "applied" sciences (pp. 21, 54-65, 61-66). Yet science in both countries, as indeed in all countries, was essentially utilitarian. Thus it is interesting that in 1910 Germany's scientific body for aeronautics, the Deutsche Versuchsanstalt für Luftfahrt (DVL), felt it necessary to defend itself against the charge of being "an unproductive scientific-theoretical organization" (p. 136). In later years German scientists and industrialists normally supported the DVL, although occasionally their interest did lag (p. 138). On the other hand, American science, while "practical", did not wholly ignore "fundamental" or "basic" fields. Thus, it was America's Wright Brothers who first studied fundamental aerodynamics with a wind tunnel (1903); it has been the superb and virtually unexcelled wind tunnels for fundamental research, built by the National Advisory Committee for Aeronautics, that have been praised almost unanimously by the aircraft and related industries; and it has been in some of America's larger corporate laboratories where basic theoretical aspects of electronics, metallurgy, and chemistry have been extensively studied (pp. 57-59, 70, 94-97).

Whether "fundamental" or "applied," scientists in industrial and government laboratories all had an ultimate practical objective in terms of a new commodity, a new process, or a new service, although the new development could not always be predicted. This utilitarian motive, common to American and German science, was essentially international. British industry, however, accepted scientists more slowly, and Japanese industry was perhaps most backward of all until prodded by official inducements of various kinds (pp. 123, 186). If the individual scientist was sometimes less interested in profit and money remuneration than in awards and honors, the firm for which he worked expanded its research program as a phase of its search for a better and wider market. If ultimate profits could not be demonstrated, or if profits from standard production commodities were threatened by new discoveries, scientific
research might be sacrificed by a firm (pp. 21, 66).

As to the attitude of scientists to war research programs, their relationship to the military has varied. As with most countries, American history has many examples of the close interrelationship between the development of peacetime products and the development of war weapons, a situation in which the impulse came as much from military requirements as from industry. For example, the steel industry was stimulated by the Navy's needs in the 1880's; the chemical industry was impelled forward by requirements of the Army in the 1890's; and the aircraft industry was essentially the result of military and other Government subsidies in the 1920's (pp. 21-23). Scientists have usually supported war research programs, although in the 1930's some of the spokesmen of British and American science castigated military projects as "the prostitution of science to war" (pp. 54-55). Nevertheless scientists have generally regarded war research favorably, sometimes initiating ideas of military value, sometimes carrying out a project initiated by the military, and sometimes "needling" the military to make better use of their talents (pp. 122-131).

Political and Financial Support

The national attitudes and elements of public opinion mentioned above are all phases of the "political support" that is needed for any research and development program. Ultimately this support becomes articulate, favorably or unfavorably, through the political and military leadership of the nation. In the United States this leadership lies, of course, in Congress and the executive branch (pp. 48, 52). Whether in democratic or authoritarian countries, the political and military leadership has had to determine a policy for earmarking a portion of the national resources for military research, and these policies reflected such pressures as conflicts between tactical arms, between strategic policies, between various elements of the national economy, and between the demands for quantity as against the quality of the airplanes and weapons. Both in Italy (pp. 161-162) and in America, for example, and probably in other countries as well, there were frequent pressures for standardization as against experimentation. Thus McCook Field in 1921 and 1922 was criticized by higher authority, even by high officers within the Air Service itself, because its experimental work was postponing quantity procurement (pp. 30-31). Similar objections were raised within the War Department in 1940 with respect to Wright Field (perhaps with greater justification than in 1921 in view of the threat of war in 1940); and the research and development program was actually partially postponed for several months.
to permit the industry to concentrate on production (pp. 82-84).
Another type of pressure was the resistance to the development of the heavy bomber in the 1920's and early 1930's, arising from conflicting strategic and tactical doctrines and viewpoints in the General Staff and the Navy. Yet during these two decades 1920 to 1940 American military leadership ultimately supported, at least passively, the Air Corps experimental program. The Air Corps was able to embark on a substantial postwar program between 1919 and 1922 (pp. 29-30); after a lapse of a decade, to initiate the heavy bomber program in 1933 (pp. 31, 38); and to undertake a 5-year program in 1939 (pp. 33-40). After 1940 there was no appreciable resistance from higher authority to the experimental program, and throughout World War II the AAF has been able to pursue a highly accelerated experimental program, together with an unprecedented production program (pp. 85-94).

Measured in terms of budgets and appropriations, the political support for aeronautical development in the United States has been uneven during the period 1914-1945. Before 1914 Congress was apathetic to military aeronautics. Between 1903 and 1913 the United States was 14th among the nations in terms of government subsidies for aeronautics (p. 23). Not until after war came in 1917 did Congress begin to support Army Aviation in any substantial measure (p.29). 
As to the other nations, Germany, France, Russia, and Italy outranked the rest of the world up to 1914 (p. 23). In World War I it was France, Germany, and England that gave the best financial support to military aviation. After the war England and the United States became outstanding, with America's air budget continuing in substantial measure as late as 1922 (pp. 31, 45, 46), in spite of the emerging period of peacetime "Normalcy" and hostility to military preparedness. The Soviet Union began to catch up after about 1927, with aeronautical research apparently a phase of its 5-year programs (pp. 148-150).
In republican Germany the Reichstag's "limited" interest after 1918 was reversed when Hitler came to power in 1933 (p. 139). British political support, which dropped in the later 1920's, began to be revived about 1936, after three years of watching the growth of Nazi Germany. American political support for aeronautical research dwindled badly between 1924 and 1934, and reached its lowest level in 1927, ironically near the moment of America's greatest financial "exhilaration" (pp. 45-47). By 1930, however, the appropriations for the NACA fortunately rose steeply (p. 53); after 1934 the Air Corps too was again being favored (p. 43); and before war broke out in Europe in 1939 Congressional support increased measurably and continued and expanded through the whole course of the "defense" period and the
"war" period down to the present (pp. 46, 99). By 1942 appropriations were so adequate that some AAF officers could "complain" that they were finding it more and more difficult to utilize the budget efficiently.

Financial support for research occasionally took other forms than research budgets as such. In Italy, for example, there were special devices for financing aeronautics, such as the system of prizes and subsidies to civil aviation (pp. 156, 160-174). In America it was a common practice in the Air Corps before 1939 to permit the contractor to amortize experimental costs with income from future production orders (pp. 70-72). Another element favorable to the research budget in most countries was that the pay of military officers engaged in experimental work did not appear in the research budgets (pp. 25, 47, 99).

By 1939 the estimated expenditures for scientific research (in all fields, aeronautical and otherwise, both for peacetime products and war goods) were about 6/10 of 1% of the national income in the United States; 5/10 of 1% in the Soviet Union; only 1/10 of 1% in Great Britain; and perhaps 3/10 or 4/10 of 1% in Germany (p. 55, 123). Since 1939 America probably has had no peer (except perhaps in the Soviet Union) in expenditures for war-related research. In 1944 about 600 millions were spent in the United States on scientific research, as against 250 millions in 1939 (pp. 111-113). In 1944 almost all of this figure was involved in war research; in 1939, only a small fraction could be charged to military and naval projects. This "total" conversion of American science to war was comparable to the conversion of other elements of the national economy, and all of this expansion reflected a "hands-off" policy of financial support for the military programs in peacetime. Once aroused, the United States had no peer in lavishing financial support on its war machine.

Organization.

Organized research has been necessary in all countries, especially in the fields of military aeronautics. Aircraft design and development is essentially a combined enterprise covering problems of military requirements, fundamental analysis, experimental design, prototype construction, service testing, and proof testing, all involving numerous agencies and institutions (pp. 15-19). Likewise the develop-
ment of airborne accessories and ground equipment in a cooperative project, involving (in the case of the AAF in World War II) the Air Staff, the Air Technical Service Command, the Proving Ground Command, the National Defense Research Committee, industrial laboratories, university scientists, and sometimes other supply services of the Army (pp. 111-121).

This situation is not unlike that in World War I. In spite of the fact that aeronautics was still largely in the pioneering stage in 1917 and 1918 in America, the Air Service had its experimental field, its wind tunnels, and its contracts with industry and civilian scientists, (pp. 25-26). There were no NACA laboratories (its first wind tunnel was not completed until 1919) and there was no proof testing organization separate from McCook Field. There was, however, a National Research Council for mobilizing scientists and industrial laboratories that were not already under contract to the Army and the Navy. Not only did the Air Service "cooperate" with the NRC; it took over the entire NRC Physics Committee, put some of them in uniform, and set them up as the Science and Research Division of the Air Service, apparently in order to maintain direct control over its experimental activities (p. 29).

Between 1919 and 1939 the most notable organizational changes affecting aeronautical research were outside rather than within the Army. The NACA expanded out of its "advisory" status in World War I to become an actual research laboratory (pp. 25, 29). Its first wind tunnel was completed in 1919, its laboratory construction program was accelerated in 1930, and by 1939 it probably had no peers throughout the world in terms of its equipment (pp. 29, 60). Another notable non-military organization in this period was the Daniel Guggenheim Fund for the Promotion of Aeronautics, established in 1925 as an endowed foundation and destined profoundly to affect aeronautical education throughout the United States. Still another scientific group was the National Research Council and its "parent body," the National Academy of Sciences, concerned with fields other than aeronautics. Their war committees were demobilized after 1918, but the main organization survived as a "scientific adviser" to whatever Federal agencies chose to use their services. Although they regarded their role as passive, the NRC and the NAS did sponsor a limited number of projects for the Air Corps before 1939 (pp. 79-81).
The Army air arm's organization for research and development has been relatively simple and consistent throughout the whole period 1917-1945. Thus, the ultimate control and supervision of the research and development program has been in the procurement-tactical arm, with its authority stemming from the Constitution itself (p. 48) and with a framework that included a system of military requirements and staff supervision in Washington (pp. 48-55). Within this arm, the work was decentralized to McCook Field (after 1927 at Wright Field). These experimental activities, furthermore, come under the same jurisdiction as quantity production and procurement, both in the AAF's single material organization and in the corporate structure of each firm in the aircraft industry. Direct collaboration with the sources of research was relatively consistent, even when there existed intermediary agencies such as the National Research Council, the National Academy of Sciences, and the National Defense Research Committee (pp. 29, 113-5). Occasionally there were reorganizations in the material agency of the AAF, but most of them were merely changes in name rather than changes in substance and policy. This organizational pattern was relatively simple, in contrast to the elaborate and sometimes overlapping organizations of scientific committees, councils, and associations thriving among civilian scientists in the United States, and in contrast to the "over-organized" scientific structure in France (p. 181) and the "overlapping and duplication" of "coordinating" bodies in Germany (p. 140).

At the same time there have been elements of organization that were rather uniform among all countries. Most of them had a NACA for both fundamental research and for coordinating fundamental research in aeronautics elsewhere. Frequently this was patterned after the American committee, although how far this similarity extended in actual practice cannot always be demonstrated. Most of them, too, had a National Research Council, such as those in Germany (1912), England (1916), the United States (1916), Italy (1921), and France (1922) (pp. 135, 122, 29, 164).

Scientific Personnel

The Army air arm's basic policy, consistent since 1917, has been to use scientific and industrial specialists in its technical projects. In World War I industrial managers from the aircraft,
automotive, and other industries, together with scientists like Millikan and Vandenberg, were given military commissions or civilian jobs in the air service in connection with research and experimental projects (pp. 20-23). Both McCook Field and Wright Field technical personnel have been preponderantly civilian ever since their origins (pp. 26, 31, 42-43). The engineers and scientists among them, both officers and civilians, frequently came from America's best technical schools and in some cases from industry, and their training was supplemented (for the officers) by the Engineering School at Wright Field and by civilian institutions like M.I.T., Cal. Tech., Michigan, and Stanford (most of them endowed by Guggenheim) (pp. 44-45). Officer attendance at such schools was authorized by Congressional legislation unsurpassed anywhere in the Army or in the rest of the Federal government (pp. 44-45). Not an unmixed blessing has been that many of them in turn have left the Air Corps to become prominent engineers in the aircraft and related industries. In World War II many Wright Field civilian experts were given military commissions, and were supplemented by aeronautical engineers commissioned from industry and by other scientists brought in both to Wright Field and Washington, including groups like those of Dr. Edward L. Hewes and Dr. Theodore von Kármán as civilian advisors to General Arnold and the Air Staff (pp. 93-94).

In both World War I and World War II the air arm has probably suffered because America's scientific manpower, especially its younger engineers, were not entirely exempt from active military duty under the Selective Service System. This was not unlike the situation in England, which in 1914 permitted one of its most outstanding young physicists (Moseley) to become a casualty on the battlefield. In World War II both England and America remedied much of this waste of scientific manpower by means of national registrations of scientists and better policies for occupational deferments, but not all problems were solved. The practices in other countries varied; France apparently was permitting no draft deferments in 1940 (p. 143), while Germany was the most consistent in mobilizing its scientists for specialized war work (p. 143). German policy was partly negated, however, by its racial and political policies which doubtless denied many scientists to them and which may have accounted for the severe drop in enrollment in technical schools between 1932 and 1937 (p. 144).
Another practice for improving military development has been to import scientists and other specialists from abroad. The Soviet Union (p. 148) and Japan (p. 185) in earlier years were the outstanding examples of such a conscious policy. After 1935, England and America, without a particularly definite national policy or a conscious scientific objective in view, did nevertheless profit by giving haven to refugee scientists.

Production of New Weapons

It is not enough to develop a new weapon or a new device. Development must ultimately give way to standardization and mass production, if the weapon is ever to leave the laboratory and face the enemy. In translating ideas into weapons in actual use, America probably has had no peer. Italy was not able to produce its unique jet plane, Germany and Japan have both been hampered in their production of new weapons in this war (p. 185), and England probably has never attained America's level of war production capacity. The wealth of America's resources for production, in terms of materials and manpower, is of course the basic explanation for this superiority (pp. 61-72). At the same time, this unexcelled capacity to produce weapons has also been a capacity to produce better weapons.

There has never been any basic, irreconcilable conflict between the needs for "quality" weapons and "quantity" production, perhaps because those who developed new material also ultimately were expected to produce it. Thus in the aircraft industry, for example, the experimental design staffs and the assembly lines are normally parts of the same firm, under the same management (p. 18). Likewise in fields outside of aeronautics, most of America's scientific research is done in industrial rather than in non-industrial laboratories, and the firm that manages the research also normally manages production. This is as true in the peacetime economy as in wartime. If American scientists have been "accused" of being preoccupied with the "practical" side of research, the reason for it is a blessing in disguise; most of America's scientists are either hired directly by industry or their university projects are subsidized by industry—by the same firm that is most likely to produce the end-product, whether a bathtub or a guided missile. This civilian/administrative pattern is the one on which the military administrative pattern is built. Thus in the AAF, both experimental engineering and production engineering functions are united under the same authority, that is, in the air material center at Wright
Field. This material center is primarily a monitor of industrial research rather than an independent laboratory, and the continuous problem both at Wright Field and in the air staff in Washington is to effect the best compromise between experimentation and production, between quality and quantity, between striving for perfection and falling in obsolescence. In addition, one specific AAF device for rationalizing these pressures should be mentioned—the system of modification centers established after 1941. By this means, newly developed equipment is installed on standard airplane models as a separate process after the plane leaves the assembly line; and ultimately at the proper, pre-determined moment, the special installation is incorporated in the assembly line with the minimum of interruption to the production process.

Strategic Planning of New Weapons

Perhaps it could be demonstrated that every scientific idea ultimately has some military value. Long before warfare was called "total war" science was regarded by the military as a useful tool of war. Today it is more than ever a basic factor in all national existence. Whether it is expedient to pursue every idea for a new weapon through the stages of research, development, and production depends, however, on a variety of factors. Among these factors are certain fundamental political and military problems: What are the strategic objectives of the Nation's military power, in terms of the potential enemy? And what are the tactical needs in terms of weapons and counter-weapons necessary for meeting the known and anticipated power of that enemy?

On the eve of World War I the small nucleus of airmen in the Army were aware of the tactical and strategic functions of air power, but no combat plane had ever been designed or built in the United States up to that time. World War I itself was for the American Air Service an operational problem on the European continent only; America's war planes were largely those developed in Allied countries for such European missions, and the Army's research and development work on airplanes was primarily devoted to modifying those European models—modifications
to suit them to American production rather than to improve their strategic and tactical effectiveness (p. 28). The Martin bomber designed and built experimentally in 1918 symbolized the rise of independent strategic thinking in the Army Air Service, and the doctrines of strategic bombardment expounded by Mitchell and others became the foundation for the Air Corps research and development program in the 1920's and 1930's (pp. 31). In 1933 the Bomb Board approved the air war plan for operations to be based on the American continent, to be directed first toward European targets and ultimately toward the Far East. The Board, furthermore, accepted the defensively self-sufficient heavy bomber as the primary weapon for the air war. In the same year the designs of the XB-15 and XB-17 were begun, and the Air Corps research and development program began in earnest, centered around this fundamental bombardment mission (pp. 35-39). The development and testing of these two models between 1935 and 1939 led directly to the heavy bombers that were used in the European theater after 1941 and the long-range very heavy bombers used in the Far East after 1943. The wartime improvements of these experimental bombers after 1939 were, of course, substantial and vital, but they were based not on any fundamental change of strategic doctrine. Instead, they represented solutions to tactical difficulties and problems encountered by the RAF and the AAF in 1940 and thereafter (pp. 82-87). The bombers planned and designed in the early 1930's were essentially those that won the air war in the German and Japanese theaters in World War II. America's fighter-bomber was acknowledged by the head of the defeated Luftwaffe as the one new weapon that helped to win the air war in Europe.

Aside from our own offensive, strategic weapons—illustrated in the strategic bomber discussed above—is the ever-present problem of countermeasures and defensive weapons for use against the enemy's new weapons. While the strategic bomber and its vital components were the "new" weapon that won the air war in Europe, the enemy was able to come forth, in the last months of that aerial combat, with its own new weapons, particularly jet fighters and guided missiles. While the ideas behind these weapons were no real "surprise" to the Allies, their tactical use at that stage of the war was unexpected, and the Allies did not achieve any basically effective countermeasures against them except to strike directly at the enemy's installations where those weapons were being produced and launched, and to push forward relentlessly with the ground and air-cooperation operations across the Continent after June 1944. Had the enemy's new missiles ap-
peared in greater strength and with greater precision a few months earlier, the Allied landings on D-Day might conceivably have been prevented. Obviously the development of countermeasures is as vital as the development of our own strategic weapons.

Whether America's present air weapons are adequate for coping with future strategic objectives is another problem. As to the remainder of the Japanese war, it can be doubted whether any new weapons not now under experimental development will be produced early enough to influence the outcome of that war. As to the immediate post-war years, with the fallen enemies remaining in a state of military collapse, it seems obvious that the best weapons now under development—the new very long range bombers, the most advanced radio and radar aids, and the newer air-launched controlled missiles—are all adequate to cope with any uprisings that may menace the security of the United States. As to the more distant future, its strategic problems are more difficult to speculate upon. Inevitably, however, the formulation of strategic objectives to meet these problems must be based on a continuous appraisal of our political and diplomatic objectives, of the political and military objectives of each of the other great powers, and of the political effectiveness of the new organization of United Nations. It is on this fundamental situation that an effective research and development program must be built. Once these strategic objectives are established, the new weapons program is likely to encounter administrative problems that are not essentially different from those that the AAF has encountered over the last 50 years. These problems, factors, and issues are those that have been discussed and explored in the attached historical studies: a sympathetic national opinion, properly cultivated by an enlightened public information program; an adequate budget supported by that national opinion and by the political and military leadership in the Congress, in the White House, and in the War Department; proper utilization of the nation's scientific talent in the laboratories of industry, of universities, of the AAF, and of other government agencies; and proper procurement programs to assure that industry remains in a stand-by condition both for development of new weapons and for their production in quantity when the need arises.
Part B:

RESEARCH AND DEVELOPMENT IN THE UNITED STATES, 1914-1944

I. INTRODUCTION

The need for new and better weapons is as old as the beginnings of organized warfare, as is the truism that better weapons can overcome an enemy having more weapons. In twentieth-century air warfare this historical truth is particularly pertinent, chiefly because of the rapid rate of obsolescence of military airplanes since 1914, during a period when international rivalry, growing commercial competition, and other pressures stimulated the development of airframes with better airfoils, power plants with better performance, and equipment with greater precision and effectiveness.

The principle that the quality of the air force's airframes must precede its quantity was not always universally accepted in the United States. In the early 1920's "there was a great deal of criticism of the Army and Navy for spending too much money on experimental work and not enough on quantity procurements." Army air spokesmen, saddled with an inventory of rapidly obsolescent planes inherited from World War I, overlooked few opportunities to point out the dangerous assumptions that lay in the rather "respectable" statistics on the strength of the Air Service, as well as the further danger that without the development of new models for the military, the infant aircraft industry (en

1. Prepared by Dr. Martin P. Clasen, APIHI, May 1945
2. The literature on the history of weapons, tactics, and organized warfare is vast. Among useful published surveys of recent date are: Tom Wintringham, The Story of Weapons and Tactics from Troy to Stalingrad (230 pp., Boston, 1943; originally published in England); George W. Gray, Science at War (296 pp., New York and London, 1943); and portions of J. D. Bernal, The Social Function of Science (462 pp., New York 1959; originally published in England). One notable collection of works and bibliographical data on military history exists in the library of the American Military Institute, housed in the National Archives Bldg., Washington, D. C.
which the Army would depend in any national emergency) would
atrophy. 4 Similar warnings were echoed and amplified by the
epidemic of Congressional and Army committees and boards that
investigated the air arm between the Armistice of 1918 and 1935. 5
Even with such repetitive hammerings at legislative and Army
opinion, the need for continuous research and development as
a basic premise of air supremacy was not unanimously acknowledged
and supported. As late as 1939 the so-called Air Board, review-
ing the experimental program for the Chief of the Air Corps
and the General Staff, found it necessary to preface its report with
the warning that "size alone ... is a minor factor" in determining
the comparative combat efficiency of America's air force. 7 The
Board went on to urge that a "more definite, effective, and con-
tinuing" research and development policy was needed; that, in
comparison, the problem of quantity production requirements was
"not a difficult task"; and that

Chief of the Air Service, 28 Feb. 1923, in AAF 475.73 Aeron-
autical Equipment (U). The aircraft production industry
was of course still in its infancy stage in the early 1920's,
without any considerable commercial source, such as the later
air transport industry, on which to thrive.
5. These committees and boards are listed in the Final Report
of War Department Special Committee on Army Air Corps /Baker
Board/, 18 July 1934, pp. 4-5. A subsequent board, the Fed-
eral Aviation Commission (Howell Commission) in 1935, should
be added. These and other legislative committee activities,
1907-35, are discussed in Organization of Military Aeronautics,
1907-1935 (Congressional & War Department Action) (AAF His-
torical Studies No. 25, 131 pp., Dec. 1944), passim.
6. For example, the Howell Commission in Jan. 1935 (its Report,
pp. 157-158) had said that if a reduced AG budget should re-
quire some retrenchment, quantity should be sacrificed to
quality. In any future emergency, quantity would be more
easily remedied than quality. "To develop a fundamentally
new type of aircraft or engine ... takes years .... Design
and development cannot be extemporized." Furthermore, the
price of development in money value should be a "secondary"
consideration.
7. Material Division, study on "Aeronautical Research and Develop-
ment," no date, about 24 April 1939, 3 pp., in AAF 400.112
Tests and Experiments (U). The wording is slightly different
in the final draft of the Air Board report, "Air Board Report,"
AG 320.2 (6-26-39), 15 Sept. 1939, tab C, p. 2; mimeographed
copy in A. J. Lyon project book No. 15-A, in office of Deputy
AG/AS HES.
Failure of the procurement planners of the Army to anticipate potential developments in such a rapidly progressing science as aeronautics inevitably will result in the supply of aircraft to the armed forces with characteristics that are ineffective against enemy weapons.

The scope of "research and development" was rather broad in Army terminology. It was a phrase to denote the experimental activities of the Air Corps, and it was a budgetary rubric common to all the supply services of the Army in 1939. Essentially it meant (for the Air Corps) the engineering, research, and testing at Wright Field in connection with the construction by industry of new or improved models of airplanes, engines, and airborne and ground equipment peculiar to air operations. It was occasionally subdivided by the Air Corps, in the directives and correspondence, into "fundamental research," such as aerodynamic analysis in wind tunnels, and "applied research." Neither of these subheadings was exclusive, however, nor was the distinction always accurate. For example, wind-tunnel tests, far from being studies in "pure science" on the theoretical aspects of air behavior, usually were applied tests of scale or full-scale models of wings or other airplane surfaces. Nor was aerodynamics the only problem involved in research and development. The development of new aerial weapons in total war potentially included research in all the natural and physical sciences, in both their "pure" and the "practical" phases. The Air Corps, however, made no distinction in actual practice, in the administration of its research activities, between these two arbitrary divisions of science and in ignoring such classifications of knowledge they apparently did not betray.

8. Ibid., tab 6, "Policy Governing Research and Development," p. 1. The observation on production requirements, which was omitted from the final draft of the report, appeared in memoranda of proposed recommendations of the "Board," no date, about May 1939, in AAF 400,112 Tests and Experiments (U).

9. Another IC classification in 1939 was "fundamental" (M.C.), "applied," (Wright Field), and "university" research, entirely omitting industry. Material Division memorandum, "Aeronautical Research and Development," no date, about 24 April 1939, in AAF 400,112 Tests and Experiments (U).
any more uncertainty and unrealism than that of the scientists themselves.10

More important than a pigeonholing or compartmentalizing of research and development was the fundamentally cooperative character of science in war (as, indeed, of science in peaceful pursuits). Especially was this true of experimental airplanes, whose complex design and construction problems had been aptly summarized shortly before by the Federal Aviation Commission:

An aircraft design is not an invention. It has passed beyond the point where it can be inspired as a whole by a single individual. Good airplanes are not the product of miraculous inspiration but usually of the coordinated effort of a design and research organization of a dozen or more groups of specialists... A design is not merely a happy idea, nor even a considerable collection of them. It is the aggregate of a great number of carefully coordinated details. It is a file of blueprints of which the collective area would in many cases literally carpet a football field. It is a five-foot shelf of books of computation and specification.11

Even this blanket view was an understatement. A combat airplane was more than such a product of a single "design and research organization." It was the resultant of ideas and suggestions from military and other Federal agencies as well, such as military requirements from the Air Corps, wind-tunnel test data from the NACA and Wright Field, flight and static test reports from Wright Field, operational suitability tests from the Air Corps.

10. For example, in a survey of the scientific activities of the Federal Government and their relation to industrial and university research, made in 1937-38 by the Science Committee of the National Resources Committee, the varying definitions of "science" and "research", "pure" and "applied", are explored (pp. 6, 62, 168 of publication cited below), including Julian Huxley's proposal for 4 instead of the traditional 2 categories; but the report proper ignores these classifications in favor of institutional and other administrative and functional groupings. See National Resources Committee, Research—A National Resource; I. Relation of the Federal Government to Research, 76 Cong., 1 sess., H. Doc. No. 122, 235 pp., 1939; as well as later volumes on Industrial Research and on Business Research.

proving ground,\textsuperscript{12} suggestions for modifications from the tactical units of the Air Corps and (after December 1941)\textsuperscript{12} from the overseas theaters of operations, and (also after December 1941) the suggestions from the Allied Air Forces. Furthermore, especially with respect to related bombardment, armament, communications, reconnaissance, navigation, and other airborne and ground equipment, the sources of ideas and experimentation included still other agencies, such as the other Army supply services (Ordnance, Signal Corps, etc.) and (again) their industrial contractors, and the university and government laboratories.

The relationship of the Air Corps to this vast cooperative effort of "science at war" comprises the bulk of this historical study: chapter II, the situation in World War I and during the immediate post-war years; chapter III, the situation in 1939 as to the military requirements, the research and development facilities of the Air Corps, and the scientific potential existing in governmental, industrial, and university laboratories; and Chapter IV the expansion of the AAF establishment for experimental engineering and for research control, 1939-44, and the changing relationships of the AAF to the wartime research activities of the Federal Government, the other supply services, their industrial and university contractors, and the research stations of the other Allies.

\textsuperscript{12} That is, the 23rd Composite Group, activated at Maxwell Field in August 1939 and moved to Eglin Field, Fla., in Dec.; and an "ancestor" of the AAF Proving Ground Command. See POG, Historical Branch, "Historical Outline . . ." (Jan. 1945), pp. 19, 20.

\textsuperscript{13} Actually, suggestions for modifying airplanes and equipment had already been coming in to Wright Field much earlier than America's entry into the war in Dec. 1941. The various AC observers in 1940-41, including the air technical section of the Chaney Mission (Army Special Observers Group) after June 1941, were concerned in large part with analyzing the combat performance and effectiveness of U.S. - produced air materiel (both lend-lease and British-imported); and their reports were of course transmitted to the U. S. for use by the Air Corps and its industrial contractors.
The basic scientific resources for developing better weapons, as discussed in this study, are intended to consist of (1) scientific personnel, (2) laboratory and experimental facilities and equipment, (3) money, (4) organization and administrative framework, and (5) a favorable public opinion. Still another category, however, might be (5) the recorded intellectual experience, whether buried in publications, archives and records, or unpublished manuscripts. If there is any truth in the assertion that "no new idea is really new," this truth stemmed in part from the fact that many recorded ideas lay buried and dormant, for the most part, in the archives and libraries of science and technology. For example, in 1939, at least 33,000 scientific periodicals were being published throughout the world, and their utilization was far from adequate either for peacetime or for wartime purposes. Even abstracts of this literature, like Chemical Abstracts, were not being fully utilized. Added to this were the mountains of unpublished manuscripts in academic, industrial, and governmental files, including the historical files in such repositories as the Library of Congress and the National Archives. Even the systematic Germans in their country were probably not ferreting out every last idea of military value from their own archives. Certainly in the United States, it was not an overstatement in 1939 that "the government—not to mention universities and industry—now has buried in its files as much in the way of intellectual resources as there are mineral resources buried underneath the soil of the North American continent."15


II. RESEARCH AND DEVELOPMENT POLICIES IN WORLD WAR I

Industrial Research by 1914

By the eve of World War I industrial research had come to have a respectable position in America's growing corporate economy. Edison's plant at Newark, established in 1869, and his Menlo Park Laboratory, 1876, had been the first outstanding early example of applied research for industrial exploitation. At the same time the General Electric Company since 1882 had been a pioneer in the use of fundamental research by industry. Behind them was a rich century of American inventive ingenuity, reflected in the development of the sewing machine, the reaper, and the typewriter, to cite only the outstanding examples. Between 1890 and 1914 laboratories became a common adjunct of industrial firms, but with a fluctuating "birth rate," as shown in the adjacent graph.

Industrial research was motivated by profit, of course, and had flourished in industry before 1914 largely because of the growing appreciation that better or new products would command a better market in the competitive world. Sometimes this motivation had an adverse effect on the exploitation of inventions and the development of new products. Thus, the Western Union Telegraph Company, it was found in 1912, "would not touch the telephone," and neither the telegraph nor the telephone companies would "touch" radio, because of the threat of these new fields to the existing production of those firms. But in general, corporate research was performing a useful social function that had a potential for both peaceful and wartime pursuits.

Among the customers for industrial research was the military. In some outstanding cases Army and Navy support to research—Government subsidies, in effect—had been the chief reason for the immediate development of a field of applied science. The development of large scale smelting of iron with coal, the steam engine, and the Bessemer process


2. No history of inventions can be included here, although the literature on the subject is substantial. Inventions, of course, derived also from sources other than industry research. For example, only 12 out of 75 of the most important inventions between 1869 and 1929 come out of corporate laboratories, according to one critic, J. D. Bernal, in The Social Function of Science (London, 1939), p. 161.

all had resulted directly from military and naval needs, and in America the Navy had substantially influenced the growth of the steel industry after 1883, and the Army, the chemical industry after 1891.

**Aeronautical Development by 1914**

Aeronautics by 1914 was the latest field where scientific development was being financially sponsored primarily in connection with war and national preparedness, but it was in Europe rather than in America where most of the official interest in military aeronautics lay. The War Department appropriation for aeronautics in 1914 totalled only $125,000, vastly less than that of any of the major European powers, and less even than Japan and Mexico. The War Department's interest in aeronautics had been sporadic, although it had not always been negative. For example, in the Civil War in the 1860's the Army had used balloons for observation and the adjustment of artillery fire. Furthermore, in 1898 it had been the Army and Navy who were most sympathetic to Samuel P. Langley's scale-model "Aerodrome" and who gave him a partial subsidy for building a full-scale model of the flying machine. However, in 1903, when Langley's machine failed to launch, the newspapers who were present damned the project with sarcasm and ridicule and the War Department chose not to take an independent view and continue its development. In the same year, the Wright brothers' first flight at Kitty Hawk, N. C., brought little response from the public, and apparently none from the War Department. In 1905 an offer by the Wrights to sell their plane to the Government was rejected, and not until after they sold their ideas in France, Britain, and Germany did the War Department become interested. The crash in 1908 of the Wright model being tested for the Army at Fort Myer did not this time deter the Army, however, and in 1909 the Wright "A" pusher was accepted from the Wright brothers.


These modest beginnings were followed by additional purchases of airplanes models from the Wrights, as well as from Curtiss, Burgess, and Martin, totalling about 39 pusher and tractor airplanes delivered to the Army by the end of 1914. None of these models had been "custom built" for any tactical use, although in 1914 the first specification for a military plane had been issued.

Military aeronautics was progressing slowly in America, and while historically most new ideas do encounter delays in their application, the fact was that America's delays were comparatively more serious than those of foreign governments. Of an estimated $86,570,000 spent between 1906 and 1913 throughout the world for military (and naval) aviation, only $435,000 had been spent by the United States, less than that spent by any other major power and less even than the expenditures of several of the minor powers: 10

<table>
<thead>
<tr>
<th>Country</th>
<th>Expenditure</th>
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<tbody>
<tr>
<td>Germany</td>
<td>$28,000,000</td>
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<tr>
<td>France</td>
<td>22,000,000</td>
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<tr>
<td>Russia</td>
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<td>Italy</td>
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<td>Austria</td>
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<td>Great Britain</td>
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<td>Belgium</td>
<td>2,000,000</td>
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<td>Japan</td>
<td>1,500,000</td>
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<tr>
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<td>700,000</td>
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<tr>
<td>Bulgaria</td>
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<td>Greece</td>
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<tr>
<td>Spain</td>
<td>550,000</td>
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<tr>
<td>Brasil</td>
<td>500,000</td>
</tr>
<tr>
<td>United States</td>
<td>455,000</td>
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</tbody>
</table>

If the government was parsimonious in subsidizing aviation development, commercial sponsorship of aviation was even less substantial, if not totally non-existent. There simply were no significant commercial outlets for aviation in 1914; the meager aircraft industry had only one customer, the United States Government. All stated in terms of aeronautical progress, America's position was equally inferior, as reported

8. Tabulation, "U.S. Army Airplanes Accepted from 1908 to January 1, 1919," no date, 3 pp., in A. S. Historical Section file 452.1 Airplanes, General.
11. Ibid., p.399.
officially in 1913:

The public has lost interest and does not support aviation as a sport; the Government has given but little aid in developing it as an adjunct to the national defense and has imposed no restrictions or regulations on its private use; the output of aeroplanes and motors in this country is inferior both in numbers and in quality to that of the foreigners; our airmen are fewer in number and of less experience; no public-spirited citizen has endowed an aeronautical laboratory as has been done in many instances abroad; our technical colleges have not offered opportunities for the scientific training of aeronautical engineers. To place the development of mechanical flight on a correct engineering basis the cut and try methods of the pioneer must give way to both theoretical and practical investigation of the laws of aerodynamics and to careful tests of machines and the materials entering into their production.

In contrast, the most hopeful sign for American aviation in 1914 was that organized aeronautical research had been begun. In 1913 the first steps had been taken to establish the National Advisory Committee for Aeronautics, and in 1915 it was given its first appropriation for the "scientific study of the problems of flight." These origins of the NACA have been described as follows:

In 1913, Dr. Charles D. Walcott, then Secretary of the Smithsonian Institution and a member of the National Academy of Sciences, proposed that an aeronautical research group be organized and that it use Langley's old laboratory in the Smithsonian building. A committee studied the matter, reported favorably, and the Advisory Committee of the Langley Aerodynamical Laboratory was set up. Among the distinguished members present at its first meeting, held on May 23, 1913, were Capt. W. L. Chambers, Glenn Curtiss, Orville Wright, Dr. Walcott, and officers of the Army and Navy. Only three meetings were held when the Comptroller of the Treasury...[ruled] that the committee could use no government funds nor personnel because it had not been established by law. So the life of the Advisory Committee of the Langley Aerodynamical Laboratory ended.

Dr. Walcott was not easily discouraged. Friends of aviation met frequently with Dr. Walcott in his home to discuss means of winning governmental support for their idea. When President Wilson was approached on the subject of establishing an aeronautics committee by law, he refused because he thought it would appear to be a warlike measure and he was trying to keep us out of the European War which had already broken out.

Finally, however, Dr. Walcott succeeded in getting his bill attached as a rider to a Naval appropriation bill, which was

passed by Congress and became law March 3, 1915, and the National Advisory Committee for Aeronautics was created—"for the supervision and direction of scientific study of the problems of flight, with a view to their practical solution" and to "direct and conduct research and experiment in aeronautics."

Congress, with some misgiving and an abundance of caution, appropriated $5,000 a year for five years, or "as much thereof as shall be necessary" for the work of the new Committee. After its first year the Committee began to receive annual appropriations from the Congress, the first of which amounted to almost $85,000. With this a modest start was made in building what later became the great Langley Memorial Aeronautical Laboratory.  

Wartime Research and Development, 1914-1918

The National Advisory Committee for Aeronautics, although it dated officially from 1915, did not acquire any laboratory facilities early enough to use in the war that followed. In April 1917, when war was declared, its facilities were still in the planning stage; four months earlier it had been promised a portion of the proposed Langley Field (Va.), selected by the Army as its own testing area as well. And the end of the war in November 1918 came before the first NACA wind tunnel could be completed, and before its new engine dynamometer buildings could be put into operation. Actually, the wartime activities of the NACA were less prominent in research than in its advisory work on other aeronautical matters—production planning, standardization, patents, and training.  

Nor had the Army's own experimental facilities passed the planning stage in April 1917. Langley Field, Va., had been accepted by the Aviation Section of the Signal Corps in December 1916 as the best of 15 sites for its "experimental station and proving ground."  

1. NACA, Annual Report, 1919, pp. 13-14; and Lt. Robert C. Hilldale, "History of...Aircraft Production...Advisory and Co-operative Agencies" (Air Service historical monograph, n.d., about 1919), pp. 1-37, in A. S. Historical Section files. Another function, that of "aeronautical intelligence," was established in 1918 for the collection and dissemination of information on American and foreign aeronautical developments, and included a "scientific attaché" in Paris.
2. Site selection, construction, and jurisdictional disputes between the Bureau of Aircraft Production and the Directorate of Military Aeronautics are all discussed in Capt. H. H. Blee, "History of Langley Field" (Air Service historical monograph, 16 Aug. 1919), in A. S. Historical Section files; copy also in AFHI.
The Aviation Section's "Engineering Organization" in Washington, consisting of Capt. V. E. Clark and five civilian engineers early in 1917, planned to move to Langley; and construction was begun in May, the month after war was declared. The Langley site was soon abandoned, however, because of its isolation from high grade help...and inaccessibility of...materials.\(^3\)

As the alternative, the McCook Experimental Field at Dayton, Ohio, was selected in 1917 because of its proximity to the airplane industry in that city and to the automobile industry in neighboring States. Some public critics later charged, however, that the site had been selected by Col. N. A. Deeds, Dayton industrialist in the Air Service, "because" of his airplanes and other interests there. Some important laboratory facilities were built at McCook before the end of the war, including dynamometer buildings; a propeller test laboratory; a 9-inch wind tunnel for calibrating air speed instruments and for studying small airfoils; and the shops for propeller woodworking, assembly of planes, and wing covering and doping.\(^4\) By November 1918 the experimental engineering personnel of McCook Field totaled 14 officers and 1,335 civilians.\(^5\) The experimental Engineering Department, under Lt. Col. Howard O. Marson (ex-Nordyke-Marson), was kept quite separate from the "Product Engineering Department" located in downtown Dayton, although both the experimental and production phases of the Air Service came under the Airplane Engineering Division headed by C. W. Nash (ex-General Motors) and Lt. Col. J. C. Vincent (ex-Packard). These agencies in turn were part of the larger Bureau of Aircraft Production, set up separately from the Signal Corps in

\(^3\) The arguments in favor of Langley in 1916 were concerned only with its general location in the east and south, its proximity to New York, and its "frontage on a large body of water." The latter factor was probably of greater interest to the Navy, which was included in the original plan. The Navy, however, also abandoned Langley, in favor of the other side of Chesapeake Bay. See "History of Langley Field" cited above; and NACA Annual Report, 1919, p. 13.

\(^4\) These facilities are described, with photographs, in "Organization and Activities of the Factory Department at McCook Field...Nov. 1917-Nov. 1918." in A. S. Historical Section file 350.06 McCook Field.

\(^5\) Compared to production engineering, which had 30 officers, 350 civilians; and "business and military," which had 15 officers, 200 civilians, and 267 enlisted men. See historical questionnaire, 7 May 1919, returned by Engineering Division, in A. S. Historical Section file 260.06 McCook Field.
May 1918 and headed by John D. Ryan (ex-Anacoda). 6

The industrial origins of these men who were placed in charge of air materiel in Washington and Dayton were diverse. Most of them came from elsewhere than the infant aircraft industry, underscoring the fact that in 1917 there was no substantial aircraft "industry" on which the Army could rely. 7 The airplane and airplane engine industry consisted of only 11 firms; its total capitalization was only $15,000,000, of which over two-thirds was controlled by two firms—Curtiss (airplanes) and Wright-Martin (engines); and the whole industry could muster only 8,000 workers, skilled and unskilled, early in 1917. The Army's total purchases of planes, up to that time, had been 39, up to the end of 1914, and 224 up to April 1917, but as yet these deliveries had not included any models designed entirely for a military use. As of early 1917, no "battle planes" had been built in the United States, and "only a handful of Americans had ever seen one. 8

The source for airplane design data in 1917 was, therefore, not American industry but the Allies in Europe, where combat-type planes had already seen action. Major A. G. Dolling was sent to England, France, and Italy in June 1917 with a mission to select models and to obtain data and samples of material. 9 Accompanying him were several Army and Navy aeronautical engineers and engine experts, and 93 representatives of the industry. Four chief models were agreed on, between the United States and the Allies, for production in the United States: the De Haviland combination fighter and day bomber, the Handley-Page night bomber, the Bristol fighter, and the Caproni bomber. Of these, the first two models were to reach quantity production before the

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6. Organization chart of Airplane Engineering Division, Bureau of Aircraft Production, Nov. 1918, in A.S. Historical Section file 360.06 McCook Field. After the Armistice, about March 1919, Material functions were reorganized into the Engineering Division (Col. Thurman H. Bane, Chief), which was a consolidation of the AP and of the Technical Section of the Director of Military Aeronautics. A small "Supply Group" was established in Washington about the same time.

7. Engineering Division, Annual Report, calendar year 1919, p. 1; copies in Pentagon Library and in AFIM.

8. The automobile industry supplied "the lion's share" of engineering talent, skilled labor, executive direction, and production techniques to the aircraft program, according to Grosvenor B. Clarkson, Industrial America in the World War.... 1917-1918 (Boston, 1923), p. 465.


9. See R.M. McFarland, "...History of the Dolling Aeronautical Mission" (A.S. Historical monograph, 29 oct. 1919); copies in AFIM and in A.S. Historical Section file 334.8 Dolling...Mission.
Armistice. 10

Some design and development of American combat models was accomplished during the war, however, notably on the Glenn Martin bomber, but no American designs reached production early enough to be tactically available by the time that the Armistice came in November 1918. Most of the experimental airplane work at McCook Field in 1917 and 1918 was concerned with modifying European models to adapt them to American production, a production engineering job rather than one of experimental engineering.

At the same time there were substantial accomplishments in America in the fields of engines and air accessories. Most notable was the 12-cylinder Liberty engine, designed by Packard and Hall-Scott engineers under contract with the Signal Corps Aviation Section in 1917. The legend that the Liberty was designed in a Willard Hotel suite in five days in May and June 1917 is only partially correct; actually it was the product of cooperative enterprise over several months, including also the work of many engineers from several other automobile firms and from the Bureau of Standards as well. 11

As to air instruments and accessories, some of the wartime developments actually did reach the production stage, notably self-sealing fuel tanks and certain visual signalling devices. Most of the approximately 57 developmental projects were either incomplete or not in production, however, when the Armistice came. A few of these projects were handled at McCook Field; but most of them were scattered among Langley Field, the Bureau of Standards, various universities (Chicago, Illinois, and Minnesota), various firms (General Electric, Bristol, Eastman, and Miller Rubber), and private individuals.

Supervising this research program was the Science and Research Division of the Signal Corps (after May 1918, a division of the Air Service), headed by two civilian scientists in uniform—Dr. (Lt. Col.) Robert A. Millikan and Dr. (Maj.) C. E. Mendenhall. 12 This group, which


numbered 22 officers, 120 enlisted men, and 16 civilian scientists by November 1918, had originated in 1917 in the Physics Committee of the new National Research Council. The Signal Corps, instead of decentralizing its research program and having the NRC handle its dealings with industry and university laboratories, was apparently interested in direct control and supervision. It asked the NRC Physics Committee to be its "advisory agent"; commissioned the key personnel of that committee; set them up as a Signal Corps division; and ultimately, on 20 May 1918, transferred the program to the new Bureau of Aircraft Production of the Air Service. After the Armistice, when most of the staff returned to civilian life, uncompleted projects were apparently taken over by the reorganized Engineering Division of the Air Service.

Post War Expenditures, 1919-1923

America's experimental activities in aeronautics in World War I were begun too late to have an appreciable effect on combat operations during the war. The real effect was to be felt, instead, during the early post-war years. By the end of the war the McCook Experimental Field had become an effective center for post-war research and development, and by 1919 the NAGA's first wind tunnel, financed by wartime appropriations, was in operation at Langley Field. Wartime expenditures of the Air Service were able to continue for seven months after the Armistice, to the end of the fiscal year in June 1919; $11,302,386 was expended on experimental projects during the whole wartime period from 1917 to June 1919. These expenditures were exclusive of additional sums such as the pay of military and civilian personnel, and were invested chiefly in the laboratory facilities and equipment at McCook Field and in a substantial inventory of experimental models of airplanes and equipment. Notable were the following experimental combat models, built before the Armistice but not in production by them:

13. The National Research Council, apparently inspired by several civilian scientists and engineers connected with the National Academy of Sciences, was established in 1916 with White House approval to make the scientific talent of the Nation more directly available on problems of national preparedness. Its establishment, one year before America entered the war, compares favorably with its British counterpart, the Department of Scientific and Industrial Research, which was organized in 1918, one year after Britain entered the war.

1. The total expenditures of the Air Service (Material, training, pay, etc.) were $1,047,107,413, out of appropriations totalling $1,691,854,758. Edgar S. Gorrell, The Measure of America's World War Aeronautical Effort (Northfield, Vt., 1940), pp. 9-8.

2. "Comments on Principal Airplanes Considered for U. S. Army Use During the War of 1917" (A. S. Historical Section tabulation, n.d., about 1919), in A. S. Historical Section file 452.1 Airplanes, General. This list includes also a number of experimental trainers, and unidentified Gallandet and Albee models.
Ordinance D 1-place "service" airplane
Stout monoplane 1-place "service" airplane
Lepere 11 2-place observation
Lepere 12 2-place fighter
Locking 2-place fighter
Thomas Morse MB-1 and MB-2 2-place fighter
Thomas Morse MB-3 1-place pursuit
Curtiss biplane 2-place pursuit
Curtiss triplane 3-place pursuit
W2-1 and 2 fighters, based on British Bristol
W2-9A and 2 bomber, 2 engine
Glen L. Martin fighter-bomber, based on British DH-4
J. V. Martin day bomber, 2-engines
Lepere triplane day bomber, 2-engine

In 1919, 1920, and 1921 McCook Field's progress reports to Washington were devoted almost entirely to experimental development and testing rather than to standardization and production. The design and (in some cases, actual construction) of experimental pursuit, attack, and observation planes; studies and layouts of other planes for night bombing, night attack, ground attack, and infantry liaison; work on air-cooled engines, cooling systems, and superchargers; and testing (and sometimes independent designing) of parachutes, leakproof tanks, photographic equipment, radio, aerial torpedoes, armament, and bomb ing equipment.

Post-war experimental activities between 1919 and 1923 were especially significant in view of the severe budget retrenchments beginning in 1919, the growing indifference toward national preparedness by the general public, and the increasing pressure for production standardization from higher authority in the Army. On the latter situation, the Engineering Division was faced with resistance from Washington, surprisingly from higher authority within the Air Service itself. On a bomb night development problem, for example, the Supply Group in Washington had this to say late

3. A total of 27 airplanes were actually designed and built at McCook Field, including the following:
   Bombers: USA-D-9, 9A, and 9B; X2-1A (12 articles)
   Attack: 9A-1 (2 articles)
   Pursuit: PW-1, 1A; TP-1; TW-1; USA-C1; VCP-1 (4 articles)
   Observation: GO-1; GO-2 (4 articles)
   Racing: M-1 (1 article)

4. The Engineering Division published a secret report on 1 Nov. 1923, entitled "Special Report to the Service," which is virtually an encyclopedia of all air matériel under development at that moment. Copy in A. S. Historical Section files.
In 1921 on the issue of production vs. experimentation. 5

If we continue this policy of buying a dab of every kind of experimental type of equipment that the Engineering Division in Dayton makes upon with the idea of conducting a service test, it would not be long before the entire Air Service would be engaged in service test work, and, should an emergency develop, it would be impracticable to put any kind of an organization in the field with the standard type of equipment.

Commenting on the same general problem shortly thereafter, the Chief of the Engineering Division commended to Colonel Wimperis, the British bombsight pioneer, that experimental work in America was suffering in the post-war period. 6

I presume you are having the same difficulty that we are in these days of economy. Unfortunately the Government is not in the hands of scientists and when an economy wave strikes, experimental development is the first thing to suffer. We rather fear that the next year will be a very trying one in a financial way.... I fear we shall have to discharge a great many engineers.

Criticism of experimental work became more and more general in the early 1930's. For the rest of the decade even quantity procurement suffered, and the experimental budget reached its lowest peak in 1927, ironically near the moment of the Nation's greatest financial "exhilaration". A small nucleus of officers and civilians did survive, however. McCook Field was able to expand into better quarters at Wright Field in 1927, and in 1933 the Air Corps was permitted to embark on its most "visionary" project and negotiate with Boeing for design data for the heavy and long-range bombers. This peacetime research and development program for bombardment, begun 6 years before the European war and 8 years before Pearl Harbor, was initiated early enough to "pay off" in the next war. It was to become the fundamental basis for the achievement of superiority in air material when America became the "arsenal of democracy" in 1940, and when the AF became a combat arm in 1941.

III. GROWTH AND ACHIEVEMENT BY SEPTEMBER 1939

Developmental Models of Air Material on Hand, 1939

When the European war began in September 1939, the status of Air Corps progress in research and development was critical. The confident official appraisals of 1934 and 1935, that Air Corps material was "equal or superior, with few exceptions, to that of any other nation," no longer applied. The Technical Staff at Wright Field in August 1939 had estimated American aviation as inferior to that of the foreign air forces, and while applauding any world progress in aeronautics "from a purely scientific viewpoint," labelled the situation "from a national defense viewpoint...[as] deplorable and one that...cannot be tolerated for long." Merely "to match, let alone exceed, the rapid progress already accomplished by other countries" would not be a simple task. This Air Corps view had been supplemented by public warnings from other leadership in American aviation, including Dr. George W. Lewis and Dr. Vannevar Bush of the National Advisory Committee for Aeronautics, and Theodore P. Wright of the Curtiss-Wright Corporation. While most of these estimates were phrased in terms of "warnings" by advocates, properly intended to provoke support for expanded aeronautical research, the fundamental accuracy of their indictment of Army air material is not challenged in any Air Corps correspondence and records used in this study.

In terms of models on hand in September 1939, the standard combat airplanes in actual tactical use in September 1939 had all been in production since 1936 or 1937: the Douglas B-18 2-engine bomber, 1937; the Northrop A-17 1-engine attack, 1937; the Seversky P-35 pursuit, 1936; and the Curtiss P-36, 1936. In terms of developmental airplane models on hand, the Air Corps

2. EJMR no. 50-651-351, 15 Aug. 1939, "Future Aeronautical Research and Development Problems," in R&D file on "FY 1942 R&D Program.
4. Ibid., 26 Jan. 1939, 912.
5. In 1934-35, on the other hand, there seems to have existed a decided disparity between undocumented warnings and demonstrable facts as to the quality of Army airplanes. The Federal Aviation Commission (Howell Commission), in its Report in Jan. 1935 (p. 127), had criticized the recent "incessant attack...upon the...inferior quality of American military aircraft," "using very available medium of publicity," while similar self-critical attacks were under way "in the very countries especially Great Britain and France" which had been held up to the United States as examples to imitate. The Baker Board had also scored the legend of American inferiority, based on a "fear...industriously cultivated in this country by various zealots" (Report, p. 10).
6. For the inventory of all adopted, developmental, condemned, and obsolete planes in Sept. 1939, see "Wartime Special Quarterly Report of Airplanes; Status of Regular Air Force, Organized Reserve, and National Guard Airplanes." 30 Sept. 1939, passim (copy in AFIH-AH).
7. Total airplanes of each model on hand in Sept. 1939 (Ibid.): 213 B-17s, B-18s; 202 A-17s, A-17s; 68 P-35s; and 171 P-36s, P-36s, P-36s, P-36s. Production dates above are taken from various editions of characteristics and performance charts, 1937-1939 passim.
position was equally critical. Of the 14 "experimental" models on hand, only 2 were new airplanes built and delivered during the year — the North American YB-21 with turbo superchargers and power turrets; and the Stearman XA-21 attack bomber. Of the total of 24 developmental models (both "experimental" and "service-test") on hand in September 1939, only 5 of these were assigned to Wright Field for experimental work, and, except for the XB-21 and XA-21, they were actually "old" as to their construction date or close similarity to older, standard models:

- XB-21 medium bomber (North American), 1937;
- XA-21 attack bomber (Stearman), 1939;
- YB-17A heavy bomber (Boeing), similar (except for engines) to XB-17 of 1935;
- XP-37 pursuit (Curtiss), built in 1937 and based on older F-36;
- XP-41 pursuit (Seversky), built in 1937 and based on P-35 of 1936;
- XP-40 pursuit (Bell), built in 1937;
- XG-35 transport (standard Lockheed "Electra"), modified in 1936 for use in high-altitude pressurised cabin research.

Two other significant developmental models were on hand elsewhere in the Air Corps: the Curtiss XP-40, built in 1939 as an improvement of the P-36A; and the Boeing XB-15, an experimental long-range bomber built in 1936, and an ancestor of the XB-29 of 1942. More promising were the models ordered but still undelivered: the XB-24, nearing completion by Consolidated (actually delivered in December 1939); the new medium bombers at North American and Martin, begun in 1938 and 1939; and the Lockheed XP-38 pursuit interceptor. 13

8. A later statement by the AAF (Eq. MG memo, "Research and Development in the AAF," no date, prepared by "Maj. D." about Feb. 1943; in NWS file "700-430 Kilgore Committee--Office of Technological Mobilisation"), that only "a single experimental airplane" was delivered in 1939 seems, therefore, to be an error. If the fiscal year 1939 was intended, the following models were delivered in 1939: XB-21, XP-39, XP-40, XP-41, XP-42. See ND, "Characteristics and Performance of U.S. Army Airplanes," 1 July 1939, sheet 8; copy in APIH.

9. Other characteristics of XB-21: 2 Pratt and Whitney R-2180 engines, each 1,400 hp, 14 cyl.; span 95', length 61', height 14', weight 19,080/27,255 lbs.; sp'd 195/220-mph; climb 10/10,000; ceiling 25,000/-; range 1,900 miles; bomb load, 4,000 lbs.; 5x.30 machine guns. MD, "Characteristics and Performance ...", 1 Jan. 1940.

10. Characteristics of XA-21: 2 Pratt and Whitney R-2180 engines, each 1,400 hp, 14 cyl.; span 65', length 53', height 14', weight 17,760/18,257 lbs.; sp'd 230/257-mph; ceiling 20,000/-; range 720 miles; bomb load, 2,000 lbs.; 6x.30 machine guns. MD, "Characteristics and Performance ...", 1 Jan. 1940.

11. 24 models, totalling 62 airplanes; there were more than one article of some of the models. "War Department Special Quarterly Report of Airplanes ...," 30 Sept. 1939.

12. The XB-15 was assigned to the CAF Air Force; the XP-40, to "miscellaneous." "War Department Special Quarterly Report of Airplanes ...," 30 Sept. 1939. Dates are from ND, "Characteristics and Performance ...", 1 July 1939.

13. The XB-17 "flying laboratory" completed the list of experimental planes on contract. MD, "Characteristics and Performance ...", 1 July 1939.
This total inventory reflected in large part the budgetary situation of the Air Corps. As explained later in retrospect, "so large a proportion of the means funds allotted that is, $3,574,290 for research and development, fiscal year 1939 were needed for the applied research 'plant overhead' at Wright Field that the completion of a single airplane or two was all that was possible in 1939." Once the budget was increased, to $10,000,000 in the new fiscal year, the relatively fixed plant overhead, while still considerable and not static, permitted "half a dozen ... complete airplane projects to be under development at Wright Field." In terms of their comparative performance, the best of these combat models were (except for attack planes) trailing the performance of foreign-developed models, especially the German. The best-performing Air Corps pursuit, the XP-37 (340 mph) was, judging by the Kilmer Board evaluation in June 1939, far behind the German ME-109-E (469 mph) and ME 112-U (440 mph), but not far behind the British "Spitfire" (362 mph), and ahead of the Italian Mc 200 (314 mph) and French Bloch 151 (304 mph). On the other hand, the best American attack models—the XA-21 (257 mph), the A-20 (395 mph), and the A-20A (347 mph)—were ahead of the French Bloch 170/174 (323 mph), the Italian Sa 55 (267 mph), and the German Ju-37 dive bomber (250 mph). Finally, the speed of the fastest heavy bomber (the XB-24, 223 mph) topped the British "Short Sunderland" (210 mph) and perhaps also the "Stirling" and "Manchester." But trailed both the Italian P-108 (250 mph) and the German Ju-39 (255 mph).

The status of propulsion, striking power, fire power, all-weather bombardment, navigational precision, and effective communication all likewise figure in any estimate of the material situation in 1939.

Inadequate power plants were, for example, the chief explanation for the lagging aircraft performance. Engine power had reached a take-off rating of 2,000 horsepower in the Wright R-1820-5, which was planned for installation in the YB-19 ordered in 1939; and 1,600 and 1,700 hp had been


15. Ibid.

16. Performance data on airplanes, even our own, are rarely absolute and definitive, and many of the data on foreign models are of course likely to be pure speculation. The figures cited above, except for the observation on the British "Stirling" and "Manchester," were those actually used in the deliberations of the Kilmer Board in May and June 1939. See its report, 22 June 1939, in A.J. Lyon project record book no. 13. See also, for varying figures, the ND chart, "Characteristics and Performance of Foreign Airplanes ...," 15 Jan 1933, in AAF 451241 "Bulk.

17. Stirling and Manchester are not listed by the Kilmer Board, but see ibid.
reached in the Wright R-2600-3 and 7, planned for use in the B-23, A-20A, and A-20. Take-off ratings between 1,000 and 1,200 hp, however, were the top limits of engines actually installed in both developmental and standard airlanes, as of about September 1939. In most cases these ratings had already been achieved in 1937 or earlier:

1,000 hp: Pratt and Whitney R-1830-11, in XB-15 (1937)
  Wright R-1920-51 and 53, in B-18A (1937), YB-17A (1939),
  and C-42 (1939), and planned for B-17B
  Allison V-1710-7, in XP-37 (1939)

1,050 hp: Pratt and Whitney R-1830-13, in P-36A (1938) and XP-42 (1939)
1,060 hp: Allison V-1710-19, in XP-40 (1939)
1,150 hp: Allison V-1710-11, in XFM-1 (1937), YF-37 (1939), and
  XP-37 (1939), and similar engines (sub-models 27, 29, 37)
  planned for YP-38 and YP-39

1,200 hp: Pratt and Whitney R-1830-13, 17, and 19, in C-41 (1938),
  P-36A and C (1938-39), YA-19 (1939), and XP-41 (1939),
  and similar engines (sub-models 33, 35) planned for
  XR-24 and YP-43
  Pratt and Whitney R-2180-1, in XB-21 (1939)

These horsepower ratings did not represent the actual frontier of research in powerplants in 1939, because there doubtless were under development improved models of these and other engines that were not yet ready for installation. Furthermore, this listing covered only the conventional internal-combustion engines. Jet propulsion, while no unit for aircraft use had as yet been achieved in the United States, was being studied at a university research project since December 1933, under an agreement between the Air Corps and the National Academy of Sciences.

As to air ordnance, the maximum bomb weight of the advanced airplane models ranged as follows: 8,000#, YIB-17A; 12,000#, XB-15; 9,040#, XB-24; and 37,000# in the XB-19, the latter only in the contract stage and not to be completed until 1941, and then only as a "flying laboratory". The maximum usable bomb size was only 2,000#, for the medium and heavy bombers; 6,000# and 1,100# for the attack models; and 20# and 30# for those pursuits (XP-40 and P-35) that could be used as fighter bombers. Airborne rockets were still in the future.

As to armament, most of the bombers in 1939 carried only .30 caliber guns, although the new YIB-17A had fittings for five .50s, and three of the seven .500s of the forthcoming XB-24 were for .50s. Fire control systems were eliminated, however. In 1937 they had been regarded by the tactical units as "practically the same as those of at least ten years ago," and wholly unfitted for the defensive missions of the unsca clinging
bomber, a tactical situation as early as 1933. In September 1939 neither the B-23, the Y1B-17A, nor the forthcoming B-17B and B-24, was equipped with turrets, while the B-18A had only a single .50 turret on top. Both in the Air Corps and among its industrial contractors, turret development was seriously trailing England and Germany. Fighter armament, on the other hand, was perhaps not as critical, although the sizes and numbers of guns were limited. 70 pursuit planes in mid-1939 had more than four fixed wing guns, although planes with more had been experimentally tested 15 and 20 years earlier—the GAX with 8 guns in 1920 and other ground strafing planes with 6 to 10 guns in 1925. Two of the experimental pursuits (the XP-39 and the XFH-1) mounted one and two .50-cal. cannon, respectively, but the experimental use of this weapon was at least as old as the considerate tests of the cannon-mounted GAX in 1920 and subsequent years.

Navigation and communications equipment in the advanced airplane models were limited in 1939 to the standard radio-gp, the marker beacon receiver, and the command and liaison sets. 25 Airborne aids for all-weather navigation and target detection and tracking were non-existent, and development was lagging, whether because of the economy budget of the Signal Corps (the Army-wide procurement agency for radio and related equipment), its greater emphasis on ground forces communications, the existence of Air Corps apathy, or other reasons. 26 Economy and cost reduction had certainly been the limiting theme in 1938 in the deliberations of the AC Technical Committee, which allocated only $6,660 for "obstacle detection and collision prevention" research, 28 a field of research which later was to contain solutions for all-weather flying and bombing-through-overcast. On the other hand, ground

23. ME, "Characteristics and Performance ...," 1 July 1939, sheet 4; and tabulation showing armament and radio equipment for all developmental airplane models, attached to E&D, Supply Division to Col. Carl Spats, Plans Section, 9 Sept. 1939, in AAF 452.1 Airplanes, General.
25. Tabulation showing radio equipment and armament for all developmental airplane models, attached to E&D, Supply Division to Col. Carl Spats, Plans Section, 9 Sept. 1939, in AAF 452.1 Airplanes, General.
27. Lt. Col. Earl H. Halden, GEQ Air Force, Chairman of ACTC Subcommittee on "item 9" (communications); other members represented the OSAC, the Signal Corps, and the Aircraft Radio Laboratory at Wright Field.
28. "Report ..." of said subcommittee, Dec. 1939, in AAF 334.8 "Bulk".
29. BTU and target detection were not mentioned in the ACTC report, but they were similar to "obstacle" detection and ultimately used some of the same solutions.
equipment for enemy aircraft warning did exist; the SCR-269 detector, which had been developed by the Signal Corps primarily for gun lasing and which gave angular (or azimuth) location of aircraft, up to 25 miles; and the portable SCR-270, which had a 100 mile range, also in azimuth only. In September the Air Board called for an "adequate" aircraft warning service, and by December 1933 the Air Corps and the General Staff were planning a new Air Defense Command to employ detectors in a coastal warning service.

The equipment for air defense was definitely inferior, however, to the best European devices, especially the British O/C equipment (range, 135 miles, showing both azimuth and altitude). Furthermore, the Air Corps was lacking the fundamentally related recognition devices (IFF). Not until Air Corps observers returned from England late in 1940 was America's inferior position to be fully appreciated in the Army and energetic steps taken to embark on a comprehensive radar development program.

Compared with the critical status of air defense aids, the guided missile situation was not as serious nor as urgent a problem in 1939. The idea of remote-controlled "aerial torpedoes" and pilotless airplanes was not new in 1939. Although there were no active developmental projects either in the Signal Corps or the Air Corps at the time, an aerial torpedo had been developed for the War Department by Charles F. Kettering in 1917. It had been mechanically rather than radio controlled, and was wholly lacking in precision even when it functioned. It had finally been abandoned by the Air Corps in 1935 because of insufficient funds, and when the idea of a preset glide bomb was revived in World War II, the AAF regarded it wholly as a temporary substitute for a precision missile. Meanwhile, the idea of radio-controlled airplanes was also a generation old in the Air Corps in 1939. Mitchell had talked about it, and in 1930 a low-powered Curtiss Robin had been purchased for experimental use in the development of an aerial torpedo. More practical, in terms of economy and immediate tactical use, had been the related radio-controlled pilotless airplane for target use in gunnery training.

33. The mission included Maj. Col. (?), A. B. McAllister and others. After its report of about 1 Dec. 1940, a "full-dress" meeting was held between the Air Corps, the Signal Corps, the Army, and the new NDC to discuss the comparative merits of British and American detection, recognition, interception, and other radar equipment. See minutes of conference, 13 Dec. 1940, in AAF 670-3 Wireless-Radio System.
36. Ibid.
The Army had completed its first successful test of such a target plane in 1934, when radio controls and automatic Flight Control Equipment were sufficiently advanced to make the project workable.

**Military Requirements and Strategic Needs, 1933-1939**

If the developmental models actually on hand in the Air Corps in 1939 did not measure up to foreign achievements, certainly the Air Corps in 1939 had a valuable inheritance of ideas and partially completed experiments from the years of peace between 1913 and 1939, covering the whole range of combat airplanes, power plants and propellers, ordnance and radio equipment, and guided missiles. Furthermore, its strategic needs were being carefully formulated.

In terms of strategic and tactical needs, the Truman Board's "air plan for the defense of the United States" of 1933 was still valid, as far as the areas of operation were concerned. This Board had visualized the army air arm as serving in its customary roles of bombardment, pursuit, transport, and reconnaissance, all toward the goal of achieving air supremacy, leading ground support, and engaging in offensive land-based air operations over land and/or sea areas with or without sea forces; and making full use of long-range reconnaissance, "decoy" of the enemy's interior installations, and "interdiction" of enemy movements. Its operational theaters were to be seven "critical areas" surrounding the United States and its outlying bases in the Western Hemisphere, and five areas corresponding to the overseas possessions of the United States. The war plans used by the Truman Board were the "Red" (British Empire), the "Orange" (Japanese Empire), and the "Red-Orange" plan, which assumed "a coalition ... with Japan." 2 In the latter plan, considered the most likely, Japan would merely be "contained," while "full power" would be exerted against "Red." The Soviet Union and China were regarded as either neutral or friendly to the United States, while Germany (in the first year of Nazi control) and Italy (still unprovocative in 1933) were ignored entirely. This political and strategic situation was the one in which the designs of the two new heavy bombers were undertaken for the Air Corps by Boeing—the "Project 299" airplane (which became the XB-17 in 1935) and the XB-15 long-range bomber (to be delivered in 1939). 3 By 1939 the seven strategic areas of 1933 were still valid, and were re-expressed by the Air Board in September 1939. 4 The potential enemy, however, had shifted.

33. AIIU historical study, "Radio and Radar Equipment for Air Operations, 1933-1944" (draft, 1944), Chap. V.


2. The latter wording is quoted from memorandum by G/16 on "Air plan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ..
violently from Britain to Germany, underscored by Nazi acts of undeclared war on the European Continent; but the strategic areas of operation were essentially the same, and the aircraft needs as visualized in the heavy and long-range bombers of 1939 were still valid, as they were restated in September 1939. The Air Board, in its report on strategic and tactical requirements made to the General Staff, reiterated the "defense" mission of Army aviation with respect to continental United States and the overseas possessions; included operations "outside of the United States and our possessions as required by the situation," and specifically mentioned both the Pacific and Atlantic sectors—the Panama-Hawaii-Alaska-San Francisco area, and the Panama-Puerto Rico-Natal area.

Meanwhile, after the appointment of the Air Board but before its report was approved, another board—the Kilner Board—was meeting (in May and June 1939) to prepare a comprehensive 5-year program for research and development for the Air Corps. The new political situation was too obvious to mention in the Board's directive. Instead, the immediate problem of military requirements, as posed in General Arnold's directive, was to prepare a program for catching up with the admittedly-superior foreign progress. Its report of recommendations, 28 June 1939, represented the views of OCAO Headquarters, of the tactical air arm, and of the material center, and consisted of a comprehensive set of proposed military characteristics for combat airplanes, related weapons and equipment, and trainer and ground-armor planes that seemed capable of actual achievement, together with an administrative plan for achieving these large objectives between 1939 and 1944, with respect to such anticipated problems as budgets, officer and civilian personnel, laboratory and other facility construction, contract and procurement procedures, and other administrative matters.

The 15 sets of military characteristics that embraced the combat and other airplane types were frankly labelled as general military objectives that would involve "a compromise between requirements for military use and technical features of design." Such compromises properly could "only be determined during design and construction by engineering calculations, and wind tunnel and flight tests." To substitute preconceived, detailed characteristics for broad objectives would "restrict the technical staffs at Wright Field and the aircraft manufacturers in determining the compromise of technical features ... for the best airplane for military use." Manufacturers working on experimental contracts must be given "wide latitude in the application of their ingenuity in meeting technical requirements of the Air Corps." 8

8. Kilner Board report (above), especially pp. 5, 9, 12-14, 10.
Among the advanced ideas brewing in the Air Corps in 1939, the following could be translated into combat material in five years or less, in the view of the Board:

Long-range bomber, achievable in 5 years: 3,000 mile range (3,000 mile radius); 400 mph; 200,000 lbs.; normal bomb load, 4,000 lbs.; dependent on development of 3,000 hp engines.

Heavy bomber: 5,333 mile range (2,000 mile radius); 375 mph above 20,000 ft.; 70,000 lbs.; normal bomb load 2,000 lbs.

Medium bomber, 2-engine: 2,697 mile range (1,000 mile radius); 400 mph; 30,000 lbs.; normal bomb load, 500 lb.

Light bomber, 2-engine: 800 mile range (300 mile radius); 600 mph at 3,000 to 5,000 ft.; light weight; normal bomb load, 1,200 lbs.

Single-engine interceptor pursuit speed, 500 mph, achievable in 2 years, dependent on new airframe and improved V-1710 and R-2800 engines.

Twin-engine pursuit fighter; speed, 500 mph, dependent on the development of a 2,500 hp engine; 300 mile range (300 mile radius).

Aerodynamics: "no radical departure ... can be depended on to obtain large increase in speed within the next two years"; improvements in wing loadings, cleaner airfoils, and more compact engine installation.

Engines: 1,300-2,400 m.p.h. and 3,000 hp engines, for fighters and long-range bombers, achievable by 1941; given very first priority.

Fire control: remote-control flexible guns for bombers; installation of cannon; adjusted forward firing of fixed pursuit guns; apparatus for medium and heavy bombers given almost top (no. 2) priority.

Among the omissions from the Board's 5-year program were jet propulsion, guided missiles, and radio aids. The limited jet research project with the National Academy of Sciences was only just getting under way, and apparently its practical future in terms of aircraft powerplants could not yet be foreseen. As to guided missiles, General Arnold had presented a Wright Field study asking for $560,000 for "special projects," including the "application of basic research ...; aircraft target, aircraft torpedo, etc.," but the Kilmer Board did not specifically include the problem in its recommendations. Radio recommendations for the new bombers and pursuit were limited to the standard communications sets and to navigation aids "for effective day-and-night operation" under all flying weather conditions. But all-weather aids, detectors, and target trackers under development by the Signal Corps were all excluded, presumably because the Board was concerned only with material under Air Corps procurement "cognizance" and not with the research programs of the Signal Corps, or (for that matter) with the programs of the other supply services of the Army such as the Ordnance Department, the Chemical Warfare Service, the Corps of Engineers, and the Quartermaster Corps.

9. Other than Air Corps combat types for which military characteristics were submitted were: Corps and Division Observation; Reconnaissance and Photographic; Primary, Basic, and Advanced Trainer; and Transport. See Kilmer Board report, tabs G through O.

10. Staff study by Material Division, no date, p. 6, in Kilmer Board Report, Appendix I.
By September 1939 the Kilner Board program had been revised downward, in connection with the immediate budget problem for the fiscal year 1941. The 8000-mile long range bomber had been deleted (but was to be revived later in the XB-35 and the XB-36), but the 5,333-mile bomber survived, as well as the other bombers, the pursuits, and the engine and fire control projects. The Air Board, which had made these revisions, went beyond the Kilner Board to emphasize that aircraft development "must be paralleled in the field of accessories, particularly armament and communications equipment, and that this latter development must be synchronized with the development of the airplane itself."

The Air Corps Experimental Establishment, 1919-1939

The laboratories, special hangars, and other experimental facilities at Wright Field in 1939 comprised a plant, valued at about $10,000,000, which had been under development since before March 1927, when the Material Division was transferred to that location from nearby McCook Field, also at Dayton, Ohio. The experimental facilities were divided largely into laboratory branches, corresponding to each of the large categories of air material: Aircraft, Power Plant, Propeller, Armament, Photographic, Equipment, Materials, Aero-Medical, and Radio; the latter a Signal Corps rather than an Air Corps installation at Wright Field. A substantial portion of each year's budget had been used for the continuous improvement of the Field. Thus, in the year beginning July 1939, $512,343 was spent for machinery and laboratory apparatus, and $190,391 for general maintenance and improvements; and $6,101,000 was earmarked for the construction of additional laboratories and other fixed equipment. The Air Corps was skillful in impressing public opinion with its "aeronautical research center" at Wright Field, and advertised much of its equipment, such as the "largest propeller test rig in the world," capable of whirling a 45-foot propeller three times as large as any standard propeller, at very high speeds (4,000 rpm) generated by a 6,000 hp motor, a motor more powerful than any locomotive engine and three times more powerful than any aircraft engine. Among other equipment were engine test stands, static test

12. War Dept., "Research and Development Program, Fiscal year 1941," table I for Air Corps, rev. 7 Sept. 1939 (blueprint copy); and AG 111 (3-30-39), 10 Aug. 1939 (copy); both in ibid. See also Air Board Report (15 Sept. 1939, tab F, p. 4, in J. J. Lyon book no. 15-A), which, with WDCS and 9/8 approval, concurred in the need for a 5,333-mile bomber (2,000 mile radius) for use in Atlantic and Pacific areas.
13. Air Board report, 15 Sept. 1939, tab G, p. 1. This recommendation on electronics was ultimately approved, in terms of Signal Corps--Air Corps ad-instractive reorganization, in the DC/3 directive of 26 Aug. 1944, which transferred jurisdiction over air communications equipment from the Signal Corps to the AAF.
1. HCR, "Army Air Forces Research and Development Program," no date, about April 1944, 19 pp., in WAP 7014.43A, Military Committee--Office of Technological Mobilization.
2. Air Corps Section of "War Department Research and Development Program, Fiscal Year 1940," 23 May 1939, in AAF 400.112 Test, Development Work. Before the war the Air Corps had opened many areas of Wright Field to the visiting public, including a historical museum set up primarily for public education. See AR 95-40, "Army Aeronautical Museum," 11 June 1942 and earlier
equipment, a 40,000-foot altitude pressure tank, and a high-altitude plane (the XC-35) pressurised at 35,000 feet. These were only a few of the 50 or more groups of specialised testing equipment on hand in 1939.

As to the research and testing staff at Wright Field, figures segregated according to research, production, and other material functions are not available, but the majority of the nearly 2,000 civilian and military personnel of the Materiel Division in 1939 were engaged on experimental, service test, and related activities, either as engineers, technical assistants, professional supervisors, or non-professional workers, all of them by and large indispensable to the operation of the laboratory branches and the technical staffs. More significant than the total personnel strength was the striking fact that of the total post strength of 1,934, 1,799 were civilians, a personnel situation that had its origins at McCook Field in 1917. Wright Field was consequently a "civilian" military post, and its long experience with the use of civilian experts in technical phases of military administration was unique in the armed services. Perhaps historically this was just as significant as the later, more-widely publicised appearance of civilians in the strategic and tactical councils of the Army in World War II. It was a common observation within the Air Corps that "the Materiel Division is run by a lot of civilians."

4. Science New Letter, 8 July 1939, pp. 26-28. This article is only one of hundred published in popular magazines during these years. No attempt is made in this historical study at a critical appraisal of the Materiel Division's public relations policy, an important element in stimulating popular appreciation for military research.

5. A convenient listing of Wright Field's equipment (as of a few years earlier: 1935), is found in the Directory of Inspection Services and Testing Laboratories of the Federal Government (published by the Treasury Procurement Division and the National Bureau of Standards, 1935), pp. 183-185; copy in NBS Library. The superseding edition (1944, same title, 261 pp.) excludes Wright Field, as well as the NACA, while at the same time listing the Navy Bureau of Aeronautical laboratories at Philadelphia.

6. Personnel strength of Materiel Division, 1 July 1939: 1,759 civilians, 149 officers, 76 enlisted men. The strength from 1935 to 1938 had been somewhat less, averaging about 1,300 civilians, 100 officers, and 46 enlisted men. See Materiel Command Historical Office, "History of the Materiel Command, 1926-1941", p. 6a.

7. Probably the most distinguished World War II examples of civilians in high military positions are Harry L. Hopkins, Chairman of the Inter-Allied Munitions Assignments Board, 1942 ff., and Dr. Vannevar Bush, Chairman of the Joint Chiefs of Staff Subcommittee on New Weapons and Equipment, 1943 ff.

8. "Special Personnel Study on Civilian Personnel of the Materiel Division ..." by Capt. C. S. Irvine, 22 Jan. 1939, p. 12, in AAF 321.1 "Bulk" files. In another connection, Gen. G. H. Brett had contrasted Wright Field with the Supply Division in Washington in that the latter lacked "suitably trained, properly equipped civilians. The backbone of any supply and engineering organization is the civilian element. Any number of specially qualified officers can be furnished but they do not take the place of the man who sits at the desk and keeps constant contact with the details of the job." Memo for C/AC by Brett, 13 Sept. 1939, in AAF 321.9 Materiel Division (U).
The Air Corps had depended largely on Civil Service personnel for many years, and the quality had been estimated as something better than the equivalent engineering personnel of the Navy Bureau of Aeronautics, composed largely of officers. 9 Not that the personnel situation was in perfect condition in 1939. Insufficiency in numbers was an obvious problem, and the Chief of the Air Corps in May 1939 had asked the Kilner Board to recommend more civilians for research and development. 10 Other more serious problems than numbers existed. A Wright Field survey in January 1939 had urged that its experimental personnel must constitute "a cross section of Air Corps officer personnel and civilian engineers, clerk-mechanics, and laborers, such as will be found in industry," and the leadership must be adequate to insure proper coordination with industry and with the tactical organizations, and to avoid dangerous errors in engineering decisions. The objective should be "a permanent Works Laboratory available for research and development, as well as for production liaison and testing for the Materiel Division and industry, and service engineering tests for the Air Corps. 12 Salaries must be higher, in order to recruit and hold on to high-caliber engineers and industrialists, and to avoid the fate in a competitive world whereby "the cream of our engineering staff will be lost and only the inefficient dregs will remain to muddle along in a typical civil-service rut." 13 In addition, the survey recommended, temporary short-term engineers and other expert consultants should be recruited to supplement the "permanent nucleus" at Wright Field, not only to infuse "new blood" into experimental activities, but also to permit rapid reenforcement if budget cuts should be threatened. A good permanent nucleus would in any case remain to insure that the spark of military progress would be kept alive in the Laboratories and on the Project drawing boards of the Division by the permanent engineers." 14

Engineering officers, compared to the civilians, were regarded as inferior in numbers and training in 1939, the survey had found. 15 For example, there

10. Memorandum for C/AC, no date, in Kilner Board report, appendix 1. The Board made no recommendation, but under the new appropriation for 1939-40 this civilian strength was virtually reached—an increase from 1,750 to 2,478 civilians. See Material Command Historical Office, "History of the Material Command, 1926-1941," p. 57.
12. Ibid., p. 15.
13. Ibid., p. 12.
15. In addition, after the Chief of the Materiel Division and his immediate staff were moved to Washington in Oct. 1939, the shortage of experienced engineering personnel applied to Washington as well. Gen. Brett complained that "Whenever a special development or research project comes up such as ... the leak-proof tank, ... fire control, redesign of equipment for speed performance, etc., officers have to be taken from other important work to be concentrated upon these developments."

An immediate remedy, he suggested, was to withdraw the 15 Wright Field officers at the AG Tactical School at Maxwell Field, and discontinue the School entirely. RBR, Brett to C/AC, 13 May 1940, in AAF 321.9 Materiel Division (U).
were only one pursuit and one bombardment project officer, each with one civilian assistant, each handling three or four projects, making it impossible to conduct adequate visits to the plants and adequate operations and planning at the field. In addition, a permanent nucleus of officers was indicated—a program that also had had the support, earlier, at the Howell Commission. 17


17. Officer training, too survey in January, 1937 had recommended a doubling of the enrollment at the Air Corps engineering School at Wright Field, and a triple increase in the assignment of officers as post-graduate students in university engineering departments. 19 Advanced university training for engineering officers had until recently been virtually non-existent for years, nor had a program been recommended by the Howell Commission in 1935. 20 The War Department had authority enough—more than that of any other Federal agency 21—to expand this training program, including enlisting legislation back to 1916 that permitted up to 25 of the Regular Officers of the Army to be detailed to such institutions. 22 The Air Corps, furthermore, had been given special authorizations, including an act of May 1, 1926, permitting as many as 25 officers to be trained in aeronautical engineering at a time, and an all-inclusive provision in the Air Corps expansion act of 3 April 1939, permitting post-graduate training "without reference to any earlier statutory limitation." 23 In terms of actual enrollment, Wright Field had sent

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10. "Special Personnel Study..." (cited earlier), pp. 9, 11-12.
17. See its Report, Jan., 1935, pp. 154-155. Both officers and civilians were included in the commissioin's idea of a "Corps of Aeronautical Engineers."
19. The AC Engineering School was the Army's center for the training of AC officers primarily for material development and production. One other Army school devoted to material matters, the Army Industrial College established about 1920, was interested primarily in industrial planning, production, and contracts on an Army-wide scale.
20. "Special Personnel Study..." (cited earlier), pp. 4, 12.
21. The Federal Aviation Commission (Howell Commission), while it spoke broadly in favor of a "corps of aeronautical engineers," made no recommendation for post-graduate training in civilian schools. This omission is especially significant in view of the Commission's membership, which included Jerome C. Bruner, then head of the M. I. T. mechanical engineering department.
22. Since 1926 no Federal survey except the War Department (whose legislative authority is cited below) had been permitted by the Comptroller General to send Government employees to technical and other civilian educational institutions. See the letter's ruling of 7 July 1926, copied in National Resources Committee, Relation of the Federal Government to Research (1939), pp. 35-37.
three officers to Michigan, C. I. T., and Stanford in September 1933 to 
study aeronautical engineering, and four officers to C. I. T., Stanford, and 
M. I. T. in September 1939. One more but hardly the triple increase re-
commended by the survey earlier in the year. In both of these enrollments, 
Wright Field and OAG headquarters were apparently operating under the 2% 
rule rather than under the broader legislation of May 1936 and April 1939. 
In any case, however, Wright Field had enough legal authority to send a 
triple or even larger complement of officers to school, if it wished, without 
the blanket act of 1939. The few dollars for tuition were, of course, no 
financial burden on the Air Corps. The small enrollments were due not to 
legal or budget limitations but probably to the shortage of officers who 
could be spared for advanced technical training.

In addition to laboratory facilities and scientific personnel available, 
the Air Corps research establishment might also be evaluated in terms of its 
appropriations and expenditures. Although money figures in themselves are 
hardly a measure either of the value of research or of accomplishment in 
terms of new and better airplanes and weapons, they were the indispensa-
ble means for providing facilities for the development of new weapons. Air Corps 
appropriations for experimental activities during the years of peace 1920-
1939 were not inconsiderable. In fact, in comparison with the research bud-
gets of other governmental laboratories, of industry, and of universities 
engaged in peacetime research, Air Corps funds were actually quite substantial.
The funds specifically earmarked for "research and development" were as follows:

24. Memorandum for AG by C/AC, 1 March 1933; and Exec., MD, to OAG Personnel 
Division, teletype, 9 May 1939, both in AAF 210.55, detail to Civilian 
Educational Institutions (U). Meanwhile, officers from elsewhere in the 
Air Corps were taking some advanced university work: 1 in 1937, 15 in 1938, 
and 4 in 1939, all in meteorology at C.I.T.; and 3 in 1939 in mathematics, 
at M. I. T.

25. As late as April 1930, the OAG Personnel Division was still invoking the 
2% rule. (See RAR, Personnel Division to MD, 12 April 1940, in AAF 210.66 
Detail to Civilian Educational Institution (U)). The 1939 enrollment was 
2.7% of Wright Field's officer strength of 149 (as of 1 July 1939). The 
statistics of 1926, 1920, and 1926 (cited above) did not, however, restrict 
an individual post to 2%. Rather, the quota applied to each Army branch 
(e.g., Air Corps) as a whole.

26. This observation is explored more fully, for example, by the National 
Resources Committee in its study on Relation of the Federal Government to 
Research (1939), p. 64.

27. For example, the AC research budget in 1937 was $4,518,460 (see tabulation 
below), which compares with the estimated research expenditures (in the 
physical and natural sciences) as follows: all Federal laboratories and 
experimental stations, $124,000,000; all industrial laboratories, $100,000,000; 
all university research programs, $51,000,000 (1935-36 estimate); and 
all endowed foundations, $3,000,000 (estimated annual average, 1919-38). 
See National Resources Committee, Relation of the Federal Government to 

Compared with the Navy and other Federal laboratories, the Air Corps stood 
as follows, in terms of percentage of the total Federal budget for re-
search in 1937 (124 millions) and 1938 (108 millions):

<table>
<thead>
<tr>
<th></th>
<th>1937</th>
<th>1938</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Corps</td>
<td>7.1%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Navy Bureau of Aeronautics</td>
<td>4.1%</td>
<td>3.1%</td>
</tr>
<tr>
<td>National Bureau of Standards</td>
<td>1.4%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Fiscal Year</td>
<td>&quot;Research and Development&quot;</td>
<td>&quot;Civilian Payroll&quot;</td>
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<tr>
<td>------------</td>
<td>----------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>1920</td>
<td>1,130,000</td>
<td>1,120,000</td>
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<td>1921</td>
<td>1,180,000</td>
<td>1,190,000</td>
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<td>1930</td>
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<tr>
<td>1931</td>
<td>1,250,000</td>
<td>1,250,000</td>
</tr>
<tr>
<td>1932</td>
<td>1,250,000</td>
<td>1,250,000</td>
</tr>
<tr>
<td>1933</td>
<td>2,153,967</td>
<td>1,167,600</td>
</tr>
<tr>
<td>1934</td>
<td>1,566,797</td>
<td>1,296,020</td>
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<tr>
<td>1935</td>
<td>1,322,394</td>
<td>1,561,315</td>
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<tr>
<td>1936</td>
<td>3,068,563</td>
<td>1,648,238</td>
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<tr>
<td>1937</td>
<td>2,568,500</td>
<td>1,657,060</td>
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<tr>
<td>1938</td>
<td>2,922,135</td>
<td>1,104,950</td>
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<tr>
<td>1939</td>
<td>2,013,409</td>
<td>1,261,560</td>
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<tr>
<td>1940</td>
<td>3,037,962</td>
<td>1,532,838</td>
</tr>
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</table>

28. Excerpt from work sheets and tabulations in WGS, including W to 40/3 (F), 40 Wgs., telegraph, no date, about 6 Feb. 1943; and data from Baker Board report, 1934; all filled in WGS "70." (D. Filmore Committee—Office of Technological Mobilization.

29. Known also in early years as "Experimental Procurement" and later as "Project 71."

30. Known also as "Project 72."

31. Known also as "Project 73."
These annual sums are in general a conservative underestimation of money actually spent by the Air Corps for research, because they did not include such considerable items as the military pay for the engineering officers at Wright Field, the expenditures for construction of laboratory and other specialized facilities, and other items that for budgetary and accounting purposes could not be labelled "Research and Development."

Substantial as these research budgets were up to 1940, there had been from year to year a striking disparity between their very slow growth (if not retrogression) and the relatively rapid increases for the Air Corps as a whole. While the research budget eventually rose from 2.6 millions in 1926 to 3.5 millions in 1939, the entire Air Corps budget mounted from 16 to 73 millions. Historically compared, 1920 to 1940, the research budgets showed still other trends: that the research budgets of the immediate post-war years of 1920, 1921, and 1922 were substantial; that they were not matched by comparably high budgets until 1936; and that during the intervening meager years 1923-1935, appropriations reached their lowest figure in 1927, ironically near the peak of America's financial expansion of that decade rather than during the depression years 1931-35. Perhaps equally ironical was the severe economy budget of the last year of peace, 3.5 millions in 1939, which, while it was larger than any Air Corps research budget in the Coolidge or Hoover administrations, was smaller than any previous budget during the Roosevelt administration.

Thus to evaluate this or that political administration, however, is as incomplete an explanation of the lag in Air Corps research funds as it is to repeat the myth that the Congress (rather than the Budget Bureau or the War Department) regularly cut the Air Corps budget estimates during these years. Funds were apparently easy to come by in the first years after World War I. Likewise after 1939, with virtually everyone on the research "bandwagon," adequate appropriations were to become progressively less a problem for the

32. For example, the fiscal year 1940 budget included, in addition to projects 71, 72, and 73 (all for research and development, civilian payroll, and service test equipment), also $6,481,000 for project 75, "additions to Laboratories, and Equipment." See AC section of "War Department Research and Development Program, Fiscal Year 1940," 23 May 1939, in AAF 400.112 Test, Development Work.

33. The research budgets of the Air Corps, the other Army supply services, and the Navy supply bureaus all are commonly an underestimate of funds actually spent, because of factors such as the above, rather than because of any conscious "hiding" of the function of research under other more innocuous headings. Civilian Federal agencies, on the other hand, have tended to hide some of their research funds under other headings as "window dressing," in order to avoid the popular stigma attached to Federal research activities. See National Resources Committee, Relation of the Federal Government to Research, (1939), pp. 63, 87, 88.


35. The fallacy of this legend is discussed in ibid., pp. 56-57.
Army Air Forces. It was during the intervening years of peace and "normalcy" when the Air Corps was starved for funds—during the very period when research and development (of all the functions of the military) could be used most effectively for national preparedness. Whether the responsibility for the curtailed budgets of the period lay at the White House, the Budget Bureau, the Congress, an apathetic or hostile public opinion, or an ineffective public relations policy by the Air Corps and the War Department, the inadequate budgets were the final, immediate explanation why the Air Corps could not explore (or subsidize) the numerous, tantalizing avenues of pure and applied science that had "possibilities" for new air weapons.

Superimposed on Wright Field's resources for development and research was an administrative and military hierarchy which controlled and supervised expenditures; assigned experimental and test projects and their priorities; formulated policy with respect to cooperative research in industry, the universities, and the other military and Federal laboratories; and sat on evaluation boards and other committees when the airplane, weapon or design, was being appraised. The authority for these responsibilities over material development was derived not only from the Air Corps Act of 1926 and the subsequent Army Regulations, but from the Constitution itself, from its grant of power to the Federal Government to "provide for the common defense," to "raise and support armies," and to maintain executive departments for carrying out these military functions. The Army, like the Navy, had a constitutional obligation to undertake research, unique in the whole Government except in the Bureau of Standards, which likewise stemmed from the Constitution. This authorization is of more than academic or antiquarian interest, in connection with the ever-recurring problem of whether the ultimate control for material development shall rest in the military, the civil agencies, or entirely outside the Government. In the most recent controversy on this point (the proposal for an Office of Technological Mobilization by Senator Kilgore in August 1942), there was an inferred threat in the bill to remove the Army (and Navy) from control over its research policy. The AAF and the other services cited all of the usual basic legislation and helped to defeat that particular proposal. Whether they were generally aware that the Constitution itself was a "trump card" in their behalf, nowhere was it invoked in the testimony or the correspondence.

36. For a history of the Act of 2 July 1926 and other legislation governing the organization of the military air arm, see "Organisation of Military Aeronautics, 1907-1935..." (AAF Historical Studies No. 25, Dec. 1944, 131 pp.).

37. AR 450-25, governing "Development...of Army Equipment," various editions (15 July 1931, 23 July 1936, and 30 June 1943); and AR 95-15, 21 April 1936, and earlier, superseded editions. AR 95-15, insofar as it applied to the Material Division's responsibilities for experimental engineering and testing, was apparently superseded by OAMG Circular 65-39 (26 March 1941), and later by AAF Regulation 65-60 (successive editions: 23 July 1943, 16 Dec. 1943, and 11 April 1944).

38. The National Resources Committee in 1937-38, surveying the nation's scientific resources (Relation of the Federal Government to Research, pp. 25, 26-27) called attention to this fact.
Immediately supervising the nine laboratory branches at Wright Field in 1939 was the Chief of the Experimental Engineering Section, Major Franklin O. Carroll, and his Technical Staff. This "ES", in turn, was (along with Production Engineering and other operating sections) a component of the Materiel Division, an organization that had been virtually free of major administrative changes affecting research, ever since its origin shortly after the Air Corps act of 1926. 39

One major change did occur in 1939, however, a trend away from the decentralization that had existed since 1926. Shortly after the outbreak of the European War, the Chief of the Materiel Division, Brig. Gen. C. H. Brett (succeeded in 1940 by Brig. Gen. Carl Spaatz and then by Brig. Gen. O. P. Echols) was moved to Washington to be in a position to advise the Chief of the Air Corps more closely on research and development, as well as on other material problems such as production and industrial mobilization. 40 Wright Field had, ever since 1926, been without direct representation in the inner councils of OAC Headquarters. The small "Material Liaison Section" in Washington had actually been a part of the Supply Division. 41 It had had no rank or prestige comparable to the other basic Air Corps functions of Training, Personnel, and Operations, and it had been abolished about September 1938. Now in October 1939, after some opposition in Washington, 42 the Chief of the Materiel Division moved to Washington, together with a small staff of

29. See Materiel Command Historical Office, "History of the Materiel Command, 1926-1941," for drafts of proposal for a Materiel Division in 1926, see AAF 321.9 Materiel Division (U). Previously, the Engineering Division at McCook Field, 1919-1926, had been concerned almost exclusively with research and development (including the actual construction of experimental airplane models for some years after World War I), while production and supply were handled by the Supply Division in Washington and the Fairfield (Ohio) Air Depot. These functions were merged shortly before their reorganization into the Materiel Division in 1926. Memorandum for G/AC by Col. C. G. Hall, Chief, Supply Division, in ibid.


41. This Section, established 14 Oct. 1926 with 1 major, 3 captains, and 4 professional civilians, was at first called "an activity of the Materiel Division." Before that time, the Engineering Division (1917-26) had occasionally had a single representative in Washington--Capt. R. L. Walsh in 1926. Memorandum for Exec., OAC by Maj. L. W. McIntosh, Chief, Materiel Liaison Section, 25 May 1927, in AAF 321.9 Materiel Division (U); and memorandum, 27 Jan. 1926, in AAF 400.112 Tests and Experiments, WP (U).

42. The Supply Division had opposed, while Plans and others favored the move. See "Organization of the Army Air Forces," 1935-43" (AAF Historical Studies No. 10, 1942), pp. 75, 76. The move apparently also had General Arnold's support. Brett at Wright Field favored the move only if it were to be accompanied by a small expert staff of civilians and officers to serve with him in Washington. Without such a staff, his section would be no better than the Supply Division (which, he said, also lacked "suitably trained, properly equipped civilians"), and he (Brett) "would be as useless as a 'fish out of water.'" Memorandum for G/AC by Brett, 13 Sept. 1939, in AAF 321.9 Materiel Division (U).
planning; officers including Major A. J. Lyon, Capt. B. F. Chidlaw, and Capt. J. F. Phillips (Maj. B. E. Meyers came to Washington later); and left his Assistant Chief, the Technical Executive, and the bulk of the technical and laboratory staffs at Wright Field. This Washington-Wright Field relationship was to continue virtually uninterrupted through the whole course of World War II, with almost no major organizational changes affecting research and development except changes in name, as shown in the adjoining chart.
Organization For Research and Development, 1926-1944

Washington

<table>
<thead>
<tr>
<th>Date</th>
<th>Material Division Liaison Section (abolished about Sept, 1938)</th>
<th>Wright Field Material Division (MD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 1926</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>May 1937 to March 1939</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>April-Sept. 1939</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>2 Oct. 1939</td>
<td>Chief, Material Division (moved to Washington, including a staff section for Experimental Engineering)</td>
<td>Assistant Chief, Material Div. including Technical Staff, Experimental Engineering section, and 9 type laboratories</td>
</tr>
<tr>
<td>Dec. 1941</td>
<td>Same, except Chief also designated as Assistant for Procurement Services</td>
<td>Same</td>
</tr>
<tr>
<td>9 March 1942</td>
<td>Same, except redesignated Material Command, including a Chief of Staff - Experimental (C/S-E)</td>
<td>Same, except redesignated Material Command, Engineering Division</td>
</tr>
<tr>
<td>29 March 1943</td>
<td>Same, except redesignated A/A Engineer, Maintenance and Distribution Material Division, Development Engineering Branch</td>
<td>Same, except redesignated Director of Material and Services, Material Command, Engineering Division</td>
</tr>
<tr>
<td>17 July 1944</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>19 July 1944</td>
<td>Same, except redesignated A/A Engineer and Services, Material Division</td>
<td>Same, except redesignated Air Technical Services Command, Engineering and Procurement Division, and Laboratories reorganized under 5 branches</td>
</tr>
<tr>
<td>31 Aug. 1944</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>November 1944</td>
<td>Same, except Material Division, Engineering Branch, and Research Liaison Branch</td>
<td>Same</td>
</tr>
</tbody>
</table>
In terms of the concepts of "centralization" and "decentralization," the Material Division had been completely decentralized since 1929, and only slightly less so after 2 October 1939. The later, widely-publicized decentralizations that were to accompany the general AAF reorganizations of 26 June 1941, 3 March 1942, and 20 March 1943 had only a slight effect on research and development policy and control. Wright Field activities continued, rather they were called the Material Division, the Material Center, the Materiel Command, or the Air Technical Service Command, while the staff office in Washington likewise merely underwent various changes in name, which, however, essentially the same leadership, the same nucleus of key officers and civilians, and the same channels over the whole period 1939-1945.

Such a schematization of the history of the Air Corps research and development organization (as above) is often as a complete oversimplification if viewed as anything but a historical directory for convenience of reference. Not only were there occasionally lesser (but more subtle if not more significant) internal administrative changes not shown above, such as the establishment of a liaison office at the NACA in 1939. There were also minor internal reorganizations that were never announced, reorganizations that were announced but never went into effect, and reorganizations that were announced months after their original significance had passed. More fundamental was that frequently the directives that led to them were based not on theories of management nor even on good historical precedent, but on changes in research and development policies, especially policies as to military and strategic requirements, testing and proving procedures, industrial and university research projects, relations with other Federal research agencies, and exchange of technical information with the Allies. It is sufficient here to outline some of the other agencies that existed in 1939 within the Air Corps and the War Department with staff functions that bore on research and development policy. Wright Field and the Material Division alone did not control policy. For example, the Field's representative on the Kaiser Board in May-June 1939 (Maj. A. J. Lyon) had been the lowest ranking officer on the Board. Other policy agencies in OCM headquarters were the following, listed in general according to echelon:

Secretary of War
AG/SP (when contracts were involved)
General Staff
Chief and Deputy Chief of Staff
AG/3 - G-4 (withdrawn from chain of command about 1941)
Budget Division (when research budgets were involved)
Air Corps Technical Committee (usually representing OCM, GTF, AG, and O3S; the Material Division supplied the Recorder after Sept. 1939)

43. Later, especially in 1944 and 1945, as the war progressed, staff officers in Washington were more and more assigned to overseas duty, such as Chidlaw in 1944, but many of the key personnel in AG/3S, AG/6S have remained.
Office of the Chief of the Air Corps
Chief of the Air Corps
OCAG Executive
Plans Section
Supply Division (concerned more with production than with research in July-August 1939)

Ordnance Department
Chemical Warfare Service
Signal Corps
Quartermaster Corps
Corps of Engineers

and their respective inter-service "technical committees" on military requirements and military characteristics, each concerned with a category of material peculiar to air operations or common to all the combat arms.

Again, this schematization, while it represents an administrative pattern that was reasonably carefully observed, is largely a stereotyped charting of research and development responsibilities. It does not show such esoteric factors as General Arnold's personal interest in stimulating research, his membership on the NACA, White House influence on national preparedness, Congressional pressures on behalf of ideas of inventions of constituents, military attaché and other observer missions abroad, special boards like the Hilker Board, and a host of other impulses, not all of them capable of segregation and individual analysis but all with varying influence on Air Corps research and development. Nor were these government agencies operating in vacuo, separate from the experimental departments of industry and the laboratories of universities. All of these elements are pertinent to any serious study of research policy.
The Scientific Potential for Air Supremacy, 1939

In Wright Field's analysis of the unsolved scientific problems confronting the Air Corps in 1939 was a basic, confident premise, that America possessed a technical capacity which could, if properly mobilized, insure American military supremacy. Its fundamental recommendation was an administrative one: "the cooperative participation of the Air Corps, the Navy, the M, A, C, A., the Bureau of Standards, the aircraft industry, and the universities." American laboratories, the survey said, cannot afford to continue to leisurely nibble at various problems but must immediately undertake...aggressive research program of wide scope but primarily devoted to the task of insuring our military supremacy. 31

Wright Field's confidence in America's aeronautical ability was matched by a widespread public confidence in America's general scientific prowess. For two decades of peace, science had been popularly regarded as an open sesame to prosperity and profit. It had become an easy confidence, almost a worship of Science. For example, advertising of newly developed commercial products in popular magazines frequently pictured, in full color, the stereotyped laboratory of test tubes, Bunsen burners, and bespectacled and be-whiskered men in white uniforms peering into the unknown. This was a national attitude common in business, industry, and advertising, and an attitude different, for example, from the British, who were more reticent if not apologetic in their publicizing of commercial products born of scientific research. 2

In both countries, however, neither commercial nor academic opinion on peacetime science was normally carried over to an enthusiasm or appreciation for war-related research, or even for government-sponsored research in general. In the years leading up to 1939, even the spokesmen of science, when they expressed themselves at all on war, usually bemoaned that the laboratory was being "prostituted" to war and that science would make war even more "horrible," and Nazi Germany was usually cited as the worst example of the use of science for anti-social goals. 3 Symptomatic of this confidence in peacetime science, coupled with an apathy if not hostility to war research, was the survey of America's scientific resources in 1937-1940 by the National Resources Committee. Its directives in 1937 and 1938 and its recommendations in 1938 and 1940 were all stated in terms of national prosperity, national welfare, and the improvement of standards of living.

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1. EMER No. 50-461-381, 18 Aug. 1939, "Future Aeronautical Research Problems," prepared by E. Ketcher, Technical Staff; in NAS file on FY 1941 AD Program. 8
all without specific reference to the war potential existing in America's laboratories. Scientists had, of course, gone a long way even to support social objectives such as the "national welfare." If they were shortsighted in 1939 about the importance of science in war, they probably merely reflected the universal complacency in America and the other democratic nations, or the common political tactic that "war" and "defense" were too indelicate to be mentioned to Americans.

A vast scientific potential did exist in America in 1939, regardless of whether it was useful for humanitarian purposes, for greater profit in business and industry, or for better weapons of war. America on the eve of the European war was spending over one half of 1% of its total national income in industrial, university, and government laboratories, a proportion greater than England's or Germany's and exceeded elsewhere in the world only by the Soviet Union. Within America's economic framework, the annual expenditures for research in the physical and natural sciences were estimated somewhat as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal laboratories and agencies</td>
<td>$120,000,000</td>
</tr>
<tr>
<td>Industrial laboratories</td>
<td>100,000,000</td>
</tr>
<tr>
<td>University and college laboratories</td>
<td>51,000,000</td>
</tr>
<tr>
<td>Endowed foundations</td>
<td>3,000,000</td>
</tr>
</tbody>
</table>

4. National Resources Committee, Research—A National Resource: Vol. I, Relation of the Federal Government to Research (Oct. 1936, 265 pp., published as H.R. Doc. No. 122, 75 Cong., 1 sess., 1939); and vol. II, Industrial Research (Nov. 1940, 370 pp.). The second volume was published by the National Resources Planning Board, successor to the Resources Committee. In fairness to the Committee, it should be noted that significant studies on phases of national-defense research were actually included in both reports. In April 1941 the National Resources Planning Board, endorsing volume II, added what sounds like an after-thought, that industrial research has "great importance in relation to both the present defense effort and also to developments in the post-defense period." (p. iii).


6. National Resources Committee, Relation of the Federal Government to Research (1939), pp. 3, 177, 180. These figures, generally as of 1937, should be further qualified in that a given sum may sometimes be represented under more than one heading, e.g., Air Corps funds transferred by contract to a manufacturer for an aircraft design. The estimate for endowed foundations is a rough annual average based on total estimated foundation expenditures ($55,000,000) for the years 1918-27.
Furthermore, it was estimated that of these research expenditures, 20% was being expended by these groups for work of potential military value even in the peaceful year 1938. The scientific potential for war existing in 1939 in these institutions—governmental, industrial, and academic—will be estimated below, together with an appraisal of the extent to which the Air Corps could and did utilize these national resources for improving its weapons for war.

**Government Resources for Research by 1939**

By 1939 Federal agencies were exercising perhaps a greater influence and importance in the field of aeronautical science than in any other area of science. Far from taking second place either to industry-sponsored or to academically-inspired research, the work of Government laboratories and the existence of Government controls were the primary impulses for the advancement of the art in the United States. The Federal Government had a "paramount interest" in aeronautics stemming from the following three elements: (1) the Civil Aeronautics Authority and its predecessor agencies in the Commerce Department, which, as the regulatory body for civil aviation, controlled airworthiness requirements of commercial planes (that is, landing and take-off performance, airplane controls, and stability) by means of technical inspection and licenses; (2) the Air Corps itself (described earlier) and the Navy's Bureau of Aeronautics, both of which, as purchasers of airplanes especially during the formative years of the aircraft industry, had "set the trend of design by their specifications to bidders," reflecting requirements which normally were "set somewhat ahead of the existing state of the art, "...based on the tactical needs of the services"; and (3) the National Advisory Committee for Aeronautics and its laboratories and facilities, through which the Government provided basic, indispensable scientific knowledge on aeronautical problems common to commercial and military airplanes, in effect a substantial subsidy for basic aeronautical research, whether for peacetime or wartime use.

7. R. V. Hallis, *Philanthropic Foundations and Higher Education* (Columbia University Press, 1938), pp. 293-294, quotes this guess, applicable both to the U. S. and Great Britain: 20%, military research; 50%, industrial and related "pure" physics and chemistry; and 25%, "agriculture and its supporting sciences." These categories are, however, hardly mutually exclusive.

The NACA has been broadly enough publici\textsuperscript{2} ed\textsuperscript{3} at least as well publicized as Wright Field\textsuperscript{5}, not to warrant detailed description here, and its scientific resources were such common knowledge in the Air Corps in 1939 that virtually all Air Corps directives and correspondence on research policy mentioned NACA in the same breath\textsuperscript{6} with Wright Field. The NACA's main sphere of activity—"scientific research on the fundamental problems of flight"—stemmed from its original Congressional mandate in 1915. Its activities had never been merely "advisory," as its name implied, and by 1939 it had had a long history of actual research activities on many problems of aerodynamics, structures, propulsion, and materials.

The Committee conducts scientific laboratory and free-flight research in the broad field of aerodynamic structures, and publishes results of value to designers affecting wing profiles and body forms, stability, and control, propellers, and methods for predicting airplane performance. It conducts theoretical and experimental research and, in general, seeks facts and principles where knowledge is lacking. This includes matters of structural strength, the combustion process and cooling of engines, and answers to many [other] fundamental questions arising from the use of airplanes....

In 1939, NACA appropriations for research, laboratory construction at Langley Field, and other activities totaled $4,085,980, of which $1,706,430 had been obligated during the fiscal year.\textsuperscript{8} These sums

\textsuperscript{2} For example, see summary by Hunsaker, in \textit{ibid.}, pp. 134-136; NACA Annual Reports, 1915-date; confidential minutes of NACA Executive Committee, disseminated to the AAF and elsewhere; and NACA references in \textit{L.I. Times Index}, \textit{Industrial Arts Index}, and other indexes to popular and technical publications.

\textsuperscript{3} The NACA apparently is subsidizing the preparation of an official history by George W. Gray, to be released to the general public; Wright Field's history is primarily for administrative reference use.

\textsuperscript{4} Naval Appropriation Act of 3 March 1915, 38 \textit{Stat.} 930. For assessments and related legislation, see U. S. Code, 50: 151, 152, 153.

\textsuperscript{5} Survey by J. C. Hunsaker (cited earlier), p. 136.

\textsuperscript{6} Regular 1939 appropriation (28 May 1938), $1,700,000, plus Supplemental (2 May 1939), $2,362,980, totaled $4,063,980. The large unexpended balance was carried over to the next year (with Congressional approval), chiefly for construction of additional facilities at Langley Field. NACA Annual Report, 1939, p. 48.
corresponded with expenditures in previous years as follows:

### Expenditures of the NASA, 1919-1939

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Total Expenditures</th>
<th>Payroll and other Personal Services</th>
<th>Facilities and Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1919</td>
<td>$204,381</td>
<td>$65,687</td>
<td>$83,447</td>
</tr>
<tr>
<td>1920</td>
<td>174,296</td>
<td>88,339</td>
<td>17,379</td>
</tr>
<tr>
<td>1921</td>
<td>199,959</td>
<td>100,836</td>
<td>19,659</td>
</tr>
<tr>
<td>1922</td>
<td>193,896</td>
<td>101,596</td>
<td>15,223</td>
</tr>
<tr>
<td>1923</td>
<td>209,591</td>
<td>95,532</td>
<td>41,784</td>
</tr>
<tr>
<td>1924</td>
<td>269,693</td>
<td>186,006</td>
<td>26,991</td>
</tr>
<tr>
<td>1925</td>
<td>437,530</td>
<td>270,191</td>
<td>98,313</td>
</tr>
<tr>
<td>1926</td>
<td>516,709</td>
<td>302,648</td>
<td>127,596</td>
</tr>
<tr>
<td>1927</td>
<td>491,920</td>
<td>341,574</td>
<td>62,763</td>
</tr>
<tr>
<td>1928</td>
<td>529,144</td>
<td>387,372</td>
<td>51,493</td>
</tr>
<tr>
<td>1929</td>
<td>611,633</td>
<td>448,771</td>
<td>67,569</td>
</tr>
<tr>
<td>1930</td>
<td>1,477,284</td>
<td>552,245</td>
<td>82,473</td>
</tr>
<tr>
<td>1931</td>
<td>1,175,514</td>
<td>617,781</td>
<td>428,842</td>
</tr>
<tr>
<td>1932</td>
<td>569,618</td>
<td>670,838</td>
<td>157,018</td>
</tr>
<tr>
<td>1933</td>
<td>827,186</td>
<td>800,045</td>
<td>99,438</td>
</tr>
<tr>
<td>1934</td>
<td>690,340</td>
<td>581,846</td>
<td>26,264</td>
</tr>
<tr>
<td>1935</td>
<td>747,827</td>
<td>616,308</td>
<td>33,914</td>
</tr>
<tr>
<td>1936</td>
<td>1,157,746</td>
<td>776,114</td>
<td>177,751</td>
</tr>
<tr>
<td>1937</td>
<td>2,337,628</td>
<td>928,537</td>
<td>1,200,262</td>
</tr>
<tr>
<td>1938</td>
<td>1,918,266</td>
<td>967,571</td>
<td>880,636</td>
</tr>
<tr>
<td>1939</td>
<td>1,706,430</td>
<td>1,066,312</td>
<td>398,265</td>
</tr>
</tbody>
</table>

In terms of facilities, the NASA in 1939 had a modest staff of about 575 engineers, technical assistants, and other employees, most of whom were located at its Langley Memorial Aeronautical Laboratory, on a site at Langley Field given to the NASA in World War I by the War Department. Its buildings and equipment, which were more...

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7. Based on NASA, Annual Reports, 1919-1939. Total expenditures include not only personal services, facilities, and equipment, but also costs of supplies, travel, communications, etc. Printing and binding are usually covered in a separate series of appropriations, excluded from the above. No ready-made tabulation such as this was available at NASA (telephone conversation with Mr. Shaw, NASA, 2 March 1945).

8. Of these employees were in Washington. Figures from NASA Personnel Office, received by telephone 28 March 1945.

9. The NASA, when it was given the space in 1919, was expected to occupy only a small portion of Langley Field, where the Army and Navy had planned to concentrate all its experimental work in aeronautics. Soon, however, the Navy moved to the other side of Chesapeake Bay, while the Army moved to McCook Field, in 1917. NASA Annual Report, 1919, p. 15.
impressive, included the following:

8-foot, 500-mph wind tunnel for testing scale models
60 x 30-foot wind tunnel for testing full-scale models
20-foot propeller-research tunnel
5-foot variable-density wind tunnel
7 x 10-foot wind tunnel
4 x 5-foot vertical wind tunnel
15-foot free-spinning wind tunnel
2 high-velocity jet-type wind tunnels with throat diameters of
11 and 24 inches, respectively
19-foot pressure wind tunnel
7 ½ x 3-foot refrigerated wind tunnel
12-foot free-flight wind tunnel
2,900-foot tank
Engine Research laboratory
Flight research laboratory
Instrument laboratory
Shops and administrative buildings

In addition, undergoing construction were a structures research laboratory, a 2-dimensional flow wind tunnel, a stability wind tunnel, a 16-foot high-speed wind tunnel, and a 20-foot free-spinning wind tunnel. At the same time at the other end of the country, a second research station (the Ames Aeronautical Laboratory)11 was about to be built at Moffett Field, Sunnyvale, Calif., after a legislative history of almost a year including the original formal proposal by the NACA in December 193812 the blessing of the White House in February 1939, and a 6-months struggle in Congress leading to the act of 9 August 1939.13 With this new laboratory, the NACA was able to double its capacity for research.

12. Maj. Gen. Oscar Westover, C/AC, on 19 Aug. 1938 had recommended to the NACA that a second laboratory be built somewhere in the interior or on the West Coast, to relieve "the congested bottleneck of Langley Field." For details on the selection of the site, see NACA, Annual Report, 1939, pp. 38-39.
13. Congressional activities that led to this act included, first, opposition and rejection of the proposal by committees of both Houses and, later, delays due to "pork-barrel measures" in behalf of other locations for the laboratory. See "Legislation Pertaining to the AAF Material Program, 1939-1944" (AAF Historical Studies No. 22, Nov. 1944), pp. 106-114.
Although appropriations were apparently no more easily obtained by the NACA than by the Air Corps before 1940, the work of the NACA was thoroughly, almost unanimously understood and appreciated by industry and the Services alike. The Baker Board in 1934 had found it "an outstanding institution" in its "pioneering work in aviation research"; the Howell Commission the next year credited the NACA for the recent "spectacular performance" of transports, and recalled there had been "no better investment" since 1918 in the national interest than the subsidies to the NACA; and the National Resources Committee in 1938 noted its "unique" function, quite "beyond the resources of any but a governmental institution," and its "high efficiency and international prestige," as shown in the fact that NACA equipment "has been, or is now being, duplicated in the great research laboratories of foreign nations." 

The Air Corps in 1939, as always, regarded the NACA as its chief resource for basic aeronautical research. Legally the NACA existed for common use by all sources—public and private—who wished to "hire" its "community service," so to speak, of wind tunnels and other facilities. This theory was modified in actual practice, in that the Air Corps and the Navy Bureau of Aeronautics—rather than either the university or industry members of the Committee—intended to exercise control by 1939. Both the Services were, of course, represented on the main Committee, the executive committee, and the various technical subcommittees, and in June 1939 this control was reinforced by the White House, which placed the NACA's research priorities and other policies under the arbitration of the Joint Army-Navy Aeronautical Board.

In addition to the NACA and the Air Corps' own laboratories at Wright Field, there was a wide variety of experimental stations among the other Federal agencies. While they were largely devoted to peacetime problems in 1939, nevertheless in total war they were convertible.

17. The Federal Aviation (Howell) Commission (in its Report, Jan. 1935, p. 228) said in 1935 that the government and the "consulting engineers and professors" dominated the NACA, and asked for greater industry representation. Sometime after 1939, the Fortune magazine (April 1942) stated that the NACA had been "dominated by the front office" of the aircraft industry. The Army and the Navy, however, seemed to be in control, especially after the White House order of June 1939.
to research in the interest of national preparedness and defense. Their existence, their facilities, and their potential values were common knowledge among the many procurement agencies of the Government. For example, there existed a comprehensive Directory of Inorganic Services and Testing Laboratories of the Federal Government, compiled a few years earlier (1935) by the Treasury Department's Procurement Division and the National Bureau of Standards. Taken together, Government laboratories were expending about 136 millions a year by 1939, more than the expenditures either by industry or the universities. Among them, the chief laboratories of interest to the Air Corps were the National Bureau of Standards, the proving grounds of the Ordnance Department, and the Signal Corps Aircraft Radio Laboratory, all of whom were working on Air Corps projects in 1939. Most notable was the Bureau of Standards, which had been helping the Air Corps for years. Hardly an annual report of McCook or Wright Fields before 1939 had failed to acknowledge the Bureau's assistance. Among other things, the Bureau had experimented with instrument landing aids for several years; with the dilution of aviation lubricants since 1935; with isomeric paraffins for high-octane fuels since 1938; and, beginning in 1939, with other problems, including beryllium and protective coatings on magnesium. In April 1939 the Secretary of Commerce (Harry L. Hopkins) took the initiative to seek more projects for the Bureau of Standards from the armed services, and the Air Corps submitted nine additional problems to them, involving tests of stainless steel, aluminum alloys, countersunk rivets, and other problems.18

Industrial Resources for Research by 1939

The extent of scientific resources existing among industrial firms of America in 1939 was rather comprehensively known. First of all, several Nation-wide inventories and surveys of industrial research were available. Among them the most comprehensive census was one


1. Among the other surveys, besides those discussed below, were the following: (1) an inventory by the National Bureau of Standards, published in July 1936 as a Directory of Commercial Testing and College Research Laboratories in Universities and Industrial Concerns (NBS publication M. 128). This directory, which covered also university research, had also been issued in earlier editions, in 1937 (publication M. 90, April and Dec. 1927) and 1929 (publication M. 90 supplement), and also came out later in a wartime edition, in 1942 (publication M. 171); and (2) a survey, for New England only, by the Engineering Societies of New England, published by them in 1939 as the Directory of New England Research and Engineering Facilities (119 pp.).
made by the National Research Council in 1938, continuing a
periodical practice going back to 1920. It was based on a
questionnaire addressed to industry, and published as a directory
of Industrial Research Laboratories of the United States. This
survey gave specific data on the names and locations of laboratories,
the names of the research directors, and the personnel strength of
the laboratories, and the fields of science represented in each of
the 1,789 laboratories listed—a ready reference for research planning
officers. The NRC survey was examined statistically and critically
in 1939-1940 by two other Federal agencies, the Work Projects Ad-
ministration and a sub-committee of the National Resources Committee.
Among the trends in 1939 shown by these surveys were the growth of
research laboratories as a phase of industrial expansion. Over 1,750
corporations in 1938 had research facilities collectively totalling
2,237 laboratories and 45,792 research personnel. This compared with
England's 435 or more laboratories, and represented a 10-fold ex-
pansion since World War I somewhat as follows:

2. Published as National Research Council Bulletin No. 102, 270 pp.
   (copy available in Pentagon Library).
   This publication was actually the 6th edition of a survey
   originally published by the NRC in 1920. See editions 1-5 in-
   clusive, published as NRC Bulletin No. 2 (1920), 16 (1921),
   60 (1927), 81 (1931), and 91 (1933), which give a comprehensive
   picture of the status and growth of commercially-sponsored
   research between World War I and World War II. A later (7th)
   edition was also published as NRC Bulletin No. 104 (Dec. 1940).

3. These evaluations were published in: George Perach, and Philip
   K. Field, Industrial Research and Changing Technology (Work
   Projects Administration, National Research Project, Report No.
   1-4, Jan. 1940, 81 pp.); and Franklin S. Cooner, "Location and
   Extent of Industrial Research Activity in the United States," in
   National Resources Planning Board (successor to National Resources
   Committee), Research—A National Resource: II. Industrial

4. Estimates by J. D. Bernal in The Social Function of Science
   (London, 1939), pp. 107-108. In another place (p. 56) his
   estimate is 300 to 500 laboratories. Bernal complained that
   only 80 of the 435 answered the questionnaire for England's own
directory of Industrial Research Laboratories, published about
1938; and it declined to give their personnel strength.
### Growth of Industrial Laboratories and Research Personnel

#### in the United States, 1920 - 1940

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Companies Reporting</th>
<th>No. of Companies Reporting total</th>
<th>No. of Labor-Reported Personals</th>
<th>Total Personnel</th>
<th>Full-Time</th>
<th>Part-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>297</td>
<td>265</td>
<td>307</td>
<td>7,357</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td>526</td>
<td>462</td>
<td></td>
<td>9,350</td>
<td>73.6</td>
<td>26.4</td>
</tr>
<tr>
<td>1927</td>
<td>999</td>
<td>926</td>
<td>1,147</td>
<td>15,982</td>
<td>74.5</td>
<td>25.5</td>
</tr>
<tr>
<td>1931</td>
<td>1,620</td>
<td>1,520</td>
<td>1,926</td>
<td>32,830</td>
<td>87.9</td>
<td>12.1</td>
</tr>
<tr>
<td>1933</td>
<td>1,562</td>
<td>1,462</td>
<td>1,834</td>
<td>27,557</td>
<td>89.7</td>
<td>10.3</td>
</tr>
<tr>
<td>1938</td>
<td>1,769</td>
<td>1,722</td>
<td>2,237</td>
<td>44,392</td>
<td>97.4</td>
<td>2.5</td>
</tr>
<tr>
<td>1940</td>
<td>2,264</td>
<td>2,280</td>
<td>3,480</td>
<td>70,033</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---


6. This excludes a small fraction of companies which, when originally surveyed by the National Research Council, 1920-38, did not choose to report the size of their staffs, or reported in such fashion that the data could not be used. (Ibid., p. 67).


Scientific research, primarily for the improvement of commercial products, was solidly established, and while some retrenchment had occurred in the depression years in the early 1930's, the business attitude toward research was more aggressive than in England, where industrial research was regarded by a British critic as "a somewhat ornamental extra to be indulged in when the firm is doing well and ruthlessly cut in bad times." In terms of expenditures, American industry was spending about $100,000,000 a year; compared to only £2,000,000 by British industry. In terms of classes of scientific specialists employed, the following trends were apparent from 1920 to 1938:

**Occupational Distribution of Industrial Research**

**Personal, 1921 - 1938**

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Over-all sample of Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1921</td>
</tr>
<tr>
<td>Number of companies sampled</td>
<td>2,355</td>
</tr>
<tr>
<td>Percent of research workers</td>
<td>100.0</td>
</tr>
<tr>
<td>Director</td>
<td>7.6</td>
</tr>
<tr>
<td>Engineer</td>
<td>15.5</td>
</tr>
<tr>
<td>Chemist</td>
<td>33.3</td>
</tr>
<tr>
<td>Physicist</td>
<td>1.3</td>
</tr>
<tr>
<td>Metallurgist</td>
<td>1.1</td>
</tr>
<tr>
<td>Other professional workers</td>
<td>14.1</td>
</tr>
<tr>
<td>Laboratory assistant</td>
<td>19.6</td>
</tr>
<tr>
<td>All others</td>
<td>5.7</td>
</tr>
<tr>
<td>Unspecified</td>
<td>0.6</td>
</tr>
</tbody>
</table>

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11. Ibid., p. 56.
13. Representative sample varying between 50 and 70% of total companies reporting. Exactly how many or what percentage of the sampled companies were in the aeronautical and allied industries is not indicated in any of the related discussions in *ibid.*
Industrial research in America, like production and distribution, was concentrated in large firms. Half of the research personnel in industry in 1939 was employed in the following 45 large companies, where the research staffs ranged in size from 172 to 4,000: 14

Aluminum Company of America
American Can Company
American Cyanamid Company
Atlantic Refining Company
Bakelite Corporation
Bell Telephone Laboratories, Inc.
Chrysler Corporation
Consolidated Edison Company of New York, Inc.
 Crucible Steel Company of America
 Dow Chemical Company
 E. I. du Pont de Nemours and Company, Inc.
 Eastman Kodak Company
 Electric Auto-Lite Company
 Firestone Tire and Rubber Company
 Ford Motor Company
 General Electric Company
 General Motors Research Corporation
 General Motors Truck and Coach Company;
   Yellow Truck and Coach Manufacturing Company
 Goodrich, N. Y., Company
 Goodyear Tire and Rubber Company, Inc.
 Gulf Research and Development Corporation
 Hercules Powder Company
 Hudson Motor Car Company
 Humble Oil and Refining Company
 International Harvester Company
 Linde Air Products Company
 Monsanto Chemical Company
 Pennsylvania Railroad Company
 Philco Radio and Television Corporation
 Pittsburgh Plate Glass Company
 RCA Manufacturing Company, Inc.
 Republic Steel Corporation
 Shell Development Company
 Sinclair Refining Company
 Socony-Vacuum Oil Company, Inc.

Standard Oil Company (Indiana)
Standard Oil Company of California
Standard Oil Company of Louisiana
Standard Oil Development Company
Sun Oil Company
United Shoe Machinery Corporation
United States Rubber Products Company, Inc.
Universal Oil Products Company
Western Union Telegraph Company
Westinghouse Electric and Manufacturing Company

The expenditures for these largest firms compared favorably with the largest of Government laboratories. Thus, du Pont’s expenditures in 1939 were 7 millions, the “largest single research budget in the U.S.A.,” compared to the Air Corps research budgets of 3.5 millions in 1939 the same year.15

As to this concentration of research in large firms, the issue of large vs. small corporations for aeronautical development was apparently not a significant one in the Air Corps in 1939. In 1935, however, the Federal Aviation (Howell) Commission had favored a few large aircraft firms rather than many small units, as being better for the national defense, and rejected the “curious argument...that the adequacy of the nation’s military aircraft industry can be gauged by the number of independent units that it contains.”16 On the other side, there was the danger, in large corporate structures, that useful inventions and designs might actually be suppressed. Whether this situation applied also to the aircraft industry itself is a subject of conjecture. In any event, in related industries there were cases where new developments were not being fully utilized. Thus Allen had been hostile to the competitive development of new aluminum processes; and the Bell Telephone System had suppressed or shelved about 3,400 unused electronics and other patents, according to revelations in 1937 by the Federal Communications Commission.17

16. Its Report, Jan. 1935, pp. 159-160. The Commission included both the development and production of air material in this recommendation. In fact, it strongly recommended that a single firm control both development and production of a given airplane or item of equipment, and that divided control was "one of the great nuisances to the development of good military aircraft." (p. 161-162).
Whether the Air Corps Material Division knew of these particular national scientific surveys and were using them in 1939-40, in the early months preceding national mobilization, it is certain that the Air Corps was fully cognizant of the extent of industry's potential both for development and for production of new airplanes and aeronautical equipment. The aircraft and allied industries—rather than Wright Field or the universities or even NACA—were and had been ever since before World War I the Army's basic source for applied research and experimentation leading up to new material. Although a few important airplanes were actually built by the Engineering Division at McCook Field, chiefly between 1917 and 1922, and while university laboratories had contributed to a number of the Army's aeronautical developments before 1939, by far the largest bulk of the work was done by industry under contract to the Air Corps, in 1939 as in virtually every other year back to the very origins of the Army's air arm in 1907. Thus, during the fiscal year beginning July 1939, over 60% of the total Air Corps research budget—6 out of 10 million—was actually being turned over to industry as payments on contracts for experimental or service-test airplanes, engines, propellers, and other equipment. This significantly high percentage was probably typical of the entire history of the Air Corps. To appreciate the scope of these subsidies to industry is fundamental to any understanding of the research and development policy of the Air Corps.

Ever since World War I, if not before, it had been a fundamental policy of the Air Service to regard experimental contracts as a means of giving support—financial and otherwise—to the aeronautical industries. For example, in 1919 the industry was in danger of being "snuffed out" by cancellations of war contracts and the return to a peacetime economy, during the "infancy" stage and before the existence of an air transport industry or other significant commercial outlets on which aeronautical manufacture could thrive. The Air Corps, the Navy Bureau of Aeronautics, and their representatives on the NACA all saw clearly and spoke frequently on the fundamental interrelationship between full government support and the growth of an industry which possessed such an enormous potential for national defense. The NACA had spoken warmly in behalf of government support in 1919, and regularly thereafter. In 1923, the Chief of the Air Service had warned of the danger to National preparedness of an insufficient research budget:

...The aeronautical industry in the United States, built up to large proportions during the war, has shrunken rapidly and is now facing extinction. Until commercial aerial transportation becomes a fact, the only demand for such equipment originates with the military branches of the Government.  

Even after the subsequent growth of commercial transport aviation, the Air Corps refused to accept air commerce as enough insurance for an aeronautical industry adequate for research and production, and the correspondence, the testimony before Congress, and the speeches and writings of Air Corps officers are abundant with pleas in behalf of fuller military and government support to aviation. In the early 1930's, as European crises began to multiply to threaten the peace of the world, the Air Corps developed another, a different tactic on the same problem, to encourage exports of standard Army airplane models by the manufacturer in order to keep the industry alive and at the same time to substitute orders for improved models of the same or other airplanes for actual delivery to the Air Corps. All of this pressure, pleading, and urging was directed primarily toward the encouragement of industry research and design of value to the Air Corps.

When war broke out in Europe in 1939, the Air Corps in its dealings with industry was on very firm ground, with a strong nucleus of aircraft and allied industries alerted for coping with the developing international situation. Of the 125 or more aircraft, engine, and other aeronautical manufacturers in 1939, the following 34 had substantial experimental design departments and laboratories:

**Airplanes**

- Curtiss-Wright, Buffalo, N.Y. (Staff of 8)
- North American Aviation, Inc., Inglewood, Calif. (6)
- Stearman Aircraft Co., Wichita, Kansas (3)
- United Aircraft Corporation, East Hartford & Bridgeport, Conn. (17)
- Vultee Aircraft Division of Aviation Manufacturing Corp., Downey Field, California. (6)

**Engines**

- Continental Motors Corporation, Detroit, Michigan. (Staff of 16)
- Lycoming Manufacturing Co., Williamsport, Pa. (6)
- Pratt & Whitney Co., Hartford, Conn. (8)

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Accessories

Aircraft Radio Corp., Boonton, N. J. (Staff of 12)
Aluminum Co. of America, Pittsburgh, Pa. (202)
American Telephone & Telegraph Co., Inc., N. Y. (Staff)
Bendix Products Division of Bendix Aviation Corp., N. J. (Staff)
South Bend, Ind. (177)
Benny Brothers, Inc., Detroit, Mich. (16)
Champion Spark Plug Co., Toledo, Ohio. (20)
Dow Chemical Co., Midland, Mich. (13)
Eclipse Aviation Corp., Bendix, N. J. (18)
Fairbanks Bearing Co., New Britain, Conn. (15)
Fairchild Aerial Camera Corp., Jamaica, N. Y. (36)
Firestone Tire & Rubber Co., Akron, Ohio, (Staff)
General Electric Co., Schenectady, N. Y. (306)
Goodrich Co., N. Y., Akron, Ohio. (Staff)
Lasee Neville Co., Cleveland, Ohio. (12)
Norme-Hoffman Bearings Corp., Stamford, Conn. (7)
Reca Manufacturing Co., Inc., Camden, N. J. (469)
Shell Petroleum Corp., St. Louis, Mo. (781)
Sinclair Refining Co., N. Y. (125)
Socony-Vacuum Oil Co., Inc., N. Y. (Staff)
Standard Oil Companies of New Jersey, (10), Pennsylvania (staff), & Louisiana, (53)
Thompson Products Inc., Cleveland, Ohio. (14)
Walter Kidde & Co., Inc., N. Y. (5 or more)
Western Electric Co., N. Y. (Staff)
Wilson-Rich Division of Eaton Manufacturing Co., Detroit, Mich. (6)

This list excluded some of the most prominent Air Corps contractors, who for one reason or another did not report their design or experimental staffs: Boeing, Consolidated, Douglas, Lockheed, and Martin, for airplanes; Allison and Wright, for engines; Curtiss and Hamilton Standard, for propellers; Kollsman and Pioneer, for instruments. Furthermore, the total research staffs of the aeronautical industries, reported at only 1,500, was a considerable understatement because, for aircraft firms, it excluded most of the aircraft design staffs and chiefly included only the wind tunnel technicians and test experts. These statistics represented, however, a considerable growth over the years of peace since 1918, a 5-fold growth from the 30 or more firms with research and design departments that existed at the close of World War I.

In addition to direct applied research on airplanes and aeronautical equipment, the Air Corps also had an appreciation of industry's resources for "basic research." Aside from the field of aeronautics, where the government-controlled NACA was supreme, basic research was a not uncommon enterprise of some of the larger corporations. The Air Corps pointed out that of these firms, the work of Alcoa, General Electric, and Eastman was best known and appreciated. Their research findings, the Air Corps stated in 1940, "quite often compare favorably with those obtained by the Governmental agencies working on pure research"; and while specific evaluation was difficult because of trade secrets, the Air Corps favored "the maintaining of old and the birth of new commercial research and development organizations of this type."

Air Corps contracts had been the method for stimulating aeronautical experimentation by industry and for keeping industry in condition for national emergencies. Contracts for military planes rather than subsidies to commercial air transportation were regarded as of greatest importance for the research program. More specifically, the easy assumption that commercial transports were quickly "convertible" to combat use had been perennially denounced by the Air Corps. The Drum Board in 1933 and the Federal Aviation (Novell) Commission in 1935 had agreed with the Air Corps. Yet all three agreed that some commercial models might be useful for the Army's lesser air missions of transport and observation.

Design competitions among aircraft manufacturers were the procedural basis, under the Air Corps Act of 1926, for arriving at developmental contracts between the industry and the Air Corps, and the traditional policy had been to permit the contractor to amortize the cost of experimental construction with income from future quantity-production orders. Both parties had been critical of this "competitive bidding" procedure. Industry occasionally objected to the unduly large risk in undertaking large projects, such as a bomber or pursuit design, which might utterly fail in the evaluation; and the Air Corps realized that the high cost of experimental aircraft, if amortized, would adversely affect the purchase of future production quantities, and if not amortized, might be an inflated cost, in effect, in cases where a given model might also later be amortized by quantity sales to other customers, such as the airlines, the Navy, or the export market.


24. Examples of competition failures and underestimates suffered by the contractors (Martin and Seversky), and overestimates suffered by the Air Corps (Curtiss P-40 and P-12, Martin M-10) are described in memorandum for G/AC by Chief, MD (written by Maj. B. H. Neyers), 21 March 1939, in AAF 334,8 Actn. "Bulk" files.
Corps objections were echoed by both the Baker Board in 1933 and the Novell Commission in 1935, both of whom favored flexible contract procedures, purchase by negotiation, and a system of fixed prices, bonuses, and penalties. In November 1938 the Air Corps asked Congress for authority to negotiate experimental contracts as an alternative to competitive bidding, and while the White House expansion program of January 1939 was before Congress, General Arnold recommended a "pay as you go" policy without amortization. Meanwhile, the manufacturers who "all know that we have a greatly increased estimate for experimental research funds [i.e., 10 millions]," were pressing Arnold to carry out a more flexible policy. Maj. B. H. Meyers, Budget Officer at Wright Field, surveying the situation historically, recommended a more forthright financial policy in order to mobilize the experimental resources of the aircraft industry: "Industry exists for profit...[and] will depend on experimentation only where a potential profit exists. Industry as it exists today cannot...be expected to deplete capital through experimentation in the interest of national defense." Most aeronautical firms were actually making substantial profits in both experimental work and production, about 12.55% on all Air Corps contracts in 1938: 10.86% on airplanes, 9.17% on engines; and 24.21% on other air equipment, but Wright Field was concerned that unpredictable and excessive development costs might weaken some elements of the industry, including at least two of the airplane firms, some of the engine firms (both small and large), and the propeller companies. The remedy lay in negotiated contracts and orderly budget

27. Memorandum for C/AC by Chief, MD (written by Meyers), 21 March 1939, in AAF 334.8 AC/T, "Bulk" files.
30. Military-financed propeller research was essential. Because of the "limited market...from the standpoint of money value, private industry cannot be expected to do the amount of highly experimental research that the situation demands." Memorandum, 10 May 1939, p. 11, in WAS file on "EAF Program, FY 1941."
planning. The Act of 3 April 1939 permitted some limited flexibility in the purchase of experimental models that had failed in design competitions, and an Act of 13 July 1939 permitted some negotiated purchasing without advertising, but only when secrecy was involved. Further legislation of 5 March and 2 July 1940 extended the authority to negotiate, and after America officially entered the war in December 1941, AAF negotiation authority was finally made complete, except for subsequent modifications affecting renegotiation and profit control, a separate problem outside the scope of this study.

University Resources for Research by 1939

University facilities in applied research were of course vastly smaller than industry's, because of the basic character of the national economy, in which research was an important tool of industry for the development of commodities for sale in the competitive market. Most of the university laboratories were devoted to fundamental phases of the physical sciences, and their projects were sponsored by various sources—industry, government, foundations, or the university itself. No detailed survey of the scientific potential in universities was available in 1939, but a few partial inventories did exist: the Bureau of Standards in 1935 had published a brief Directory listing the broad fields of university research; one of the educational directories gave a few facts on the physical plant of universities as of 1938; and the National Resources Committee in 1939 surveyed general trends of university research. The latter survey revealed some important general information on universities, such as: that the trained scientific personnel of universities totalled 9,100; that research expenditures per year totalled $51,000,000, in some cases constituting 25% of a university's total income; and that America's university achievements in pure science had not been as "remarkable" as Europe's. The survey was not detailed, however. Only 60 of 200 institutions had replied to the Committee's questionnaire; scientific apparatus and plant facilities were not covered; and the potential for national defense was barely mentioned. Furthermore, none of these surveys were specific enough—on to facilities, subjects of research, or manpower—for administrative use in the planning of a military research program.

31. 53 Stat. 580, 1000.
32. For the legislative history of Air Corps negotiated contracts procedures in 1939-1940, see "Legislation Relating to the AAF Material Program, 1939-1944" (AAF Historical Studies No. 22), especially pp. 82-93, 101, 152.
In the field of aeronautics, university research facilities were vastly more limited than the facilities of either industry or Government, and so it is not surprising that the Air Corps relied little on direct contracts with them. While 60% of the entire Air Corps research budget in 1939 was seeping down among the aeronautical industry's experimental departments and design staffs, only one seventh of one percent ($15,000) was being disbursed to universities, and that on a single university contract, a project on fog dissipation at the Massachusetts Institute of Technology. Indirectly, however, the Air Corps had several university projects under way in 1939, notably a small rocket and jet propulsion project at the California Institute of Technology, sponsored by the National Academy of Sciences, and various NACA contracts with universities since 1935, costing about $25,000 annually.

It was apparently an assumption in 1939 that the Air Corps, if it utilized university research at all, would normally contract for it through the NACA and the NAS rather than directly. Neither the Baker Board in 1935 nor the Noyce Commission in 1936 included references to the Air Corps in their recommendations on university research on aeronautics, an especially significant omission because a university administrator sat on each of the boards. Similarly, both the Killinger Board and the NACA research subcommittee in 1939 inferred that university research for the Air Corps would be handled indirectly through the NACA. Yet the Material Division did have at least one direct contract with a university in 1939, and the Air Corps frequently expressed its theory of research management as being one of "direct collaboration" with the scientist—whether academic, industrial, or bureaucratic. Furthermore, Wright Field by 1939 was regularly sending a few of its outstanding engineering officers to universities to pursue postgraduate training pertinent to their specialties. Three such officers in September 1939 were entering M. I. T., C. I. T., and Stanford for this purpose.

2. Table of Contents, FY 1940-44 Inclusive, in NAS "AAFP Research and Development Program," about April 1944, in NAS files 700,450 "...Kilgore Committee." This single project had likewise been the Air Corps' only university project in 1937. (Memo for G-4 by C/AC, 10 Dec. 1937, in AAF 400.112 Tests and Experiments [U]).

3. Other NAS "basic research" projects, presumably to be placed with universities, were covered in an AC-NAS contract (W335-coll170) in June 1939: de-icing of antenna masts; true plastic; reduction of reflection from glass and plastic surfaces; and use of artificial radio-active compounds in luminous materials. See 1st ind., (basic unknown), OMAS to MD, 9 June 1939, in AAF 337 Conferences.

4. NACA, Annual Report, 1939, p. 39. The NACA proposal in 1939 to expand this university program 10-fold met the "strenuous objection" of the Budget Bureau. See NACA Executive Committee, minutes, 16 Nov. 1939, pp. 2-3, in AAF 400.112 NAC.
The Air Corps student at M. I. T., Capt. Alfred R. Maxwell, who was prominent in bombardment development, saw in the aeronautical departments of America's best technical schools a resource that the Air Corps ought to tap more fully, and he sent the Materiel Division his views and recommendations. He was "surprised" at the "extensive" aeronautical research facilities at M. I. T., whose work "certainly compares favorably with that of the NACA," and warned that while the Air Corps was taking "little advantage" of it, the Navy, the CAA, the NACA, the Corps of Engineers, and firms like Sperry and General Electric all had "successful projects" under way there. Generalizing about M. I. T. and similar institutions, Maxwell cited the impressive amount of advanced knowledge hidden away in thesis files, department notes, and professors' brains, little of which joins the fund of common knowledge in the form of texts, papers, NACA reprints, etc., or if it does, it is late. I find that many NACA publications concern work done originally at schools, but by the time it is reviewed and published there is a time lag.

Student thesis research, particularly, was a field for the Air Corps "to tap," he said, and while theses were usually "excellently" executed, their contributions to engineering were frequently "nil" because the students were not always guided to practical research topics. Students would welcome a list of practical thesis subjects submitted by the Air Corps, he believed. Financially, too, the Air Corps would gain: the Air Corps could easily get title to theses at a cost of "little or nothing"; contracts with universities would tend to be more economical than industrial projects because the professors were accustomed to getting "little or nothing from the contractor"; and, in any exchange with the Army, the universities would probably be grateful for a few modern condemned engines, instruments, etc., from the Air Corps to replace the antiquated 2-12 Liberty engines, the JN-5 Jenny* planes, and similar equipment on hand.

5. Capt. Maxwell (later Col. Maxwell, Director of Bombardment, and Chief of OCMR Bombardment Branch, 1943-44) was preparing thesis on a phase of bombardment: determination of criteria for design of high-performance automatic controls suitable for use in gyro pilots, bombights, and servo mechanisms in general, with particular emphasis on improvement in performance by the use of rate controls. See memo for Chief, MD, by C/AC, 22 May 1943, in AAF 310.06 Detail Officers—Civilian Educational Institutions (U); Memo for Commandant, AC Engineering School, by Maxwell, 31 March 1943, in AAF 301—Maxwell, A. E.; and memo for Decorations and Awards Branch by AC/AS, OCMR, 9 Sept. 1944, in ibid.

Maxwell's estimate of the university research situation was read by various officers in OAC Headquarters, and General Arnold ordered it sent to the NACA's new "Coordinator of Research," rather than to Wright Field. Apparently it was discussed in the NACA meeting two days later, when the NACA was directed by its Executive Committee to make a nation-wide survey of research facilities of schools, universities, and other "individual organizations" throughout the country, as well as an inventory of potential research projects at Wright Field (and presumably at the Naval aircraft factory as well) that might be suitable for allocation to universities.

This inventory in February 1940 was apparently the first usable survey of aeronautical research laboratories in universities in recent years, and while it remained unpublished, it contained actual facts and figures to bolster the Lindbergh committee's generalizations of six months before, and provided the Air Corps with an estimate of America's scientific potential in the aeronautical fields. Substantial laboratory equipment and trained personnel were found to exist in 75 educational institutions, many of which were subsequently visited by NACA officials. In subsequent months, 30 research projects were to be initiated by the NACA with some of them, in the field of aerodynamics (6), structures (10), materials (6), and power plants (9). Meanwhile, the Air Corps was also to expand its university program.

Control and Coordination of Military Research, 1939

Governmental control and supervision over scientific work in America was non-existent in 1939 in terms of a nation-wide mobilization of scientists and laboratories for national defense. There was nothing in the United States comparable to the German or Italian dictatorship over industry and education, nor anything comparable to the Soviet collectivist system for the management of technology and production, nor even anything comparable to the nationalized aircraft industry of France of 1936. However, even in the United States in 1939 there was certainly much more control over science by governmental agencies than was publicly admitted by many of the vocal spokesmen for

8. XI-19 (prepared by Capt. B. W. Chidlaw, MD), 23 Feb. 1940, in ibid.
9. The Directory published in 1936 by the National Bureau of Standards (previously cited) included "college research laboratories" but omitted such well-known facilities as C. I. T. and M. I. T.; and its format, arrangement, and code names made it difficult to use.
industry and science. The nature and extent of government control and coordination of industrial, university, and government laboratories had been comprehensively examined by the National Resources Committee in 1939, in which a rich and varied tradition of government coordination of research was seen at least as far as the patent system established by the Constitution, or the agricultural experiment stations begun in 1862. It is a totally inaccurate legend that scientists in universities and industry were working "freely," uninfluenced by government guidance and interference, whether for humanitarian, national-preparedness, or other social causes.

Specifically, the Air Corps in 1939, as discussed earlier, was supervising aeronautical research in numerous ways. This control was exercised in terms of specific situations and specific problems: discretion in selection of this or that private organization for the execution of a research project, especially where competitive conditions did not exist; control over the allocation and expenditure of funds; engineering and testing of specific experimental articles; and the final evaluation of the end product itself. There was nothing unusual or sinister in this traditional relationship between the military and the scientist. It was such a common relationship, so well founded in historical precedent in the American economy, that it wasn't even consciously an issue in 1939.

Yet was this military-civilian, governmental-private relationship necessarily "harming" on the development of new airplanes or other equipment. The so-called historical legend, that new weapons have usually been developed in spite of the "traditional" animosity and conservatism of military authorities, if it is correct at all, is hardly correct for Army aviation between World War I and World War II, when military requirements had normally been somewhat ahead of the state of the art and when the Air Corps research budget had subsidized most of America's advanced aeronautical developments. Conservation here and there did exist, of course, but far from being peculiar to the military, it was likely to be equally characteristic of an engine firm.

1. See its publication, Relating of the Federal Government to Research (Washington, 1939; 255 pp.)
2. J. C. Merriam, The Social Function of Science (London, 1935), p. 182. (See incidently contralects this statement, however, with specific examples cited elsewhere, where he "describes" the efficient but "constructed" use of science by the military. Other critics have uttered the same observation as to military conservatism toward new weapons, including George W. Gray and Deser Krempfert.
3. The current resistance to jet propulsion research by some of the conventional engine firms about 1940-42 is an example. The lag in the commercial application of new inventions is also interesting in this connection. See J. C. Gilfillan, "Prediction of Inventions," in National Resources Committee, Technological Trends and National Policy... (Washington, D.C., 1932, No. 346, 76 Cong., 1 sess., June 1937), part 2, Art. 15-22.)
a university engineering department, a government laboratory, or at least portions of each. In whatever type of institution, both conservative and liberal attitudes were likely to prevail side by side, and the development of new weapons were comparably affected.

The issue of "control" was not whether there should or should not exist governmental supervision over scientific research, but rather how extensive it should be, and in which particular governmental agency that control should be vested. As the responsible procurement agency for air materiel for the Army, based on Act of Congress and Army Regulation, the Air Corps in 1939 was obviously interested in keeping the closest control over its research contracts with private organizations, as well as over the relevant research projects in other governmental laboratories. To be interested in anything less than close supervision and control would have been to shirk responsibility and to abdicate its fundamental material mission.

Among the other government agencies that were in any comparable position to exercise control over aeronautical research and development, the NACA was the most pliable and historically in the best position. In 1939 the NACA was not only an active participant in research, as described elsewhere, but it was also performing a coordinating function over the aeronautical sciences, a task described by one of the NACA members as follows:

a coordinating function by means of subcommittees consisting of experts from the Government agencies and from various branches of the industry. Research projects are initiated or approved by appropriate subcommittees. Some projects are assigned, by contract, to university or other laboratories where special facilities or qualified personnel exist.6

Furthermore, the NACA since 1918 had been collecting information and data on the progress of foreign aeronautical developments, through its "scientific attaché" in Paris as well as by other means. None of these

4. The British physicist and critic of research administration, J. B. S. Haldane, caustically criticized his colleagues in British universities thus: "A scientific theory is generally thought to require a quarantine of some forty years before it is safe for elementary students." The Social Function of Science (London, 1933), pp. 77-78.
5. J. C. Hunsaker, "Research in Aeronautics," in National Resources Planning Board, Research and Industrial Research, p. 136. Professor Hunsaker, at that time (1940) was in charge of the Department of Aeronautical Engineering at M. I. T., as well as a member of NACA. Later he became chairman of the NACA.
coordinating activities were new in the NACA except for the sponsorship of university research, which had not been undertaken until after 1936. This relatively new field was defended in 1939, if it needed a defense, as a device intended not only to yield new contributions to knowledge but also for "the training of research workers in aeronautics for the benefit alike of the governmental services and the industry"; and Government subsidies were defended as an "effective," "economical," and "democratic" procedure for furthering "what has become an international competition" in national preparedness.

The Air Corps in 1939 was inclined to defer to the NACA for the coordination of the fundamental phases of aeronautical science, since the Air Corps (together with the Navy Bureau of Aeronautics) could effectively control the Committee's policies and decisions, not only through their membership on it and on its subcommittees, but also through the Joint Army-Navy Aeronautical Board, which was given emergency jurisdiction over the NACA in June 1939. However, in accepting this situation, General Arnold had warned that fundamental research should not be rigidly separated from "applied" and "production" research by a "Chinese wall," and that if the NACA should become the coordinator of fundamental research, it needed "new blood and [should be] expanded sufficiently to assume this function." Subsequently a Director of Coordination had been established in the NACA, in June 1939, with the blessing of both the Executive Committee and the special Lindbergh Committee; and in January 1940 the Coordinator (S. Paul Johnston) was appointed. How extensive or effective this coordination would be was still in doubt. The Air Corps, even with military control of NACA assured, in general preferred direct collaboration with contractors working on its projects, unless the research project clearly had broad Army-Navy-commercial aspects. A further reason for direct liaison, suggested by Captain Maxwell at M. I. T. and probably widely accepted in the Air Corps, was that the engineering students and faculties tended to regard the NACA as "rather impersonal and overcritical," and "only a source of technical literature," while the Air Corps was

6. NACA, Annual Report, 1939, p. 3.
7. The White House on 28 June 1939 approved a proposal made in Aug. 1938 by the NACA Special Committee on Relationship of (NACA and) National Defense in Time of War, of which General Oscar Westover, then Chief of the Air Corps, was chairman. See NACA Executive Committee, minutes, 15 Sept., 1939, pp. 9-10, in AAF 400,112 NACA.
"living and glamorous to most, and a goal of quite a few."

Any coordination by the NACA, furthermore, was concerned only with fundamental research, and only in the fields of aerodynamics, structures, power plants, fuel, and some of the aircraft materials. Important as they were, they excluded such equally basic material as air ordnance, electronic aids, optical aids, alloys, and numerous other types and phases of air materiel, whose improvement was all vital to the achievement of air supremacy. These fields of military research, as far as the Army was involved, were under the primary cognizance of Army technical services other than the Air Corps, such as the Ordnance Department, the Signal Corps, and the other services; and the Air Corps, both as a supply service and as a combat arm, was intimately associated with those services through direct collaboration and through the formal channels of Technical Committees (existing for these various categories of material) and the divisions of the General Staff.

Beyond these Army-wide controls and a few formal but insignificant Army-Navy channels on research, there existed in 1939 a skeleton organization for research coordination that might be convertible to national defense purposes. This organization was the National Research Council, which had been the two agencies in World War I to mobilize America's scientific resources for that war. After 1919 the NRC survived in more limited form, under the National Academy of Sciences, as a permanent "scientific adviser" to the Federal Government. Its membership, totalling about 700 in 1920, was rather broad, representing, as it did, about 55 national scientific and technical societies, as well as the various Federal scientific bureaus and agencies, and a limited number of members chosen at large; and its various divisions and subcommittees totalled about 1,150 additional scientists and professional men. In addition to its supervision of a limited number of technical projects for various agencies, it also disseminated useful information vital to the more effective administration of research, notably its periodic series of Industrial Research Laboratories in the United States, the latest of which had been published in 1935. In 1939, the NRC, at the request of


the National Resources Committee, was going beyond this inventory to make "a study of the capacity of industrial corporations in the United States for scientific research, and especially the trends of the research undertaken by the laboratories of these firms." This survey, while it was apparently not made for national defense purposes, did contain many conclusions easily convertible into recommendations on national preparedness on the scientific front.12

In 1939 the National Research Council and its parent body, the National Academy of Sciences, were perhaps a "passive" influence, as far as the coordination of science for national defense purposes was concerned. They were receptive enough to problems submitted to them, but they were not authorized to go beyond this and actively seek out scientific problems confronting the military procurement services; and they usually spoke with some pride that their mission was "not to volunteer to seek out projects of interest to the Government.13 Within this framework, the Academy was sponsoring a number of projects submitted by the various supply services, including a number of Air Corps problems previously mentioned in this study. Beyond these problems, and the limited funds supporting them, the Air Corps was unwilling to go. Thus, the Air Corps, when asked early in 1940 whether its liaison with the NRC could be improved, acknowledged the value of NRC contacts with scientists and pointed to the list of projects mentioned above; but reiterated its fundamental policy of "direct collaboration" with outside agencies. Illustrating its position by the technical problem of bombing-through-overcast (BTO), the Chief of the Air Corps pointed out the need for close, but direct, collaboration between the military and the civilian scientist in these phases: (1) to determine the scope of the problem; (2) to summarize the probable means and methods of its solution, and to agree on "the most practical approach"; and (3) to determine whether a solution were "feasible" if applied to military aviation, and if applied, whether the "application" would be "practicable" from a tactical and production standpoint. These phases of the problem, he urged, required "open round-table discussions between the scientist and the practical engineer,"

12. The end product of this survey was the 370-page report of the NRC to the FPB, Dec. 1940, entitled Research--A National Resource: II. Industrial Research (Washington, 1941). Some of its conclusions and facts have already been quoted.

13. Later testimony as to the passive character of the NAS and the NRC are given in Hearings,... S. 2722, before the Senate subcommittee on Technological Mobilization, Oct.-Dec. 1942, pp. 8, 12, 14, 76-77, 368. One of the witnesses, M. M. Whitaker, went further (p. 357), to criticize the NAS as conservative and "self-perpetuating," as "austere body...of mature years...; crystallized in their ideas and their viewpoint...conservative...."
and "direct collaboration" with outstanding authorities in physics, aerodynamics, optics, and metallurgy. That any intermediary supervision by an outside body, once the parties were brought together, would serve no useful purpose, was clearly implied.

War Department attitudes toward other proposals for scientific coordinating bodies was similar. A proposal in Congress in April 1938 for a "developmental center for the Army" had been opposed because of the existing system of facilities and the existing coordinating functions in the Washington offices of the supply services and the General Staff, and because such a new agency would become "a super agency, independent of the supply services and using arms and dictatorial as to all matters of equipment." The bill was never passed. A later Congressional proposal, early in 1939, for a more limited body, one primarily for "military aircraft engineering" but covering both the Army and the Navy, was likewise rejected. This time after objections by the two services jointly as well as by the Air Corps separately. There were still other proposals brewing in 1939, but whether the new agency was to be a War Department Board, a joint committee, or a Federal-wide organization, the Air Corps consistently objected to any administrative changes what would reduce direct collaboration or add to the hierarchy of supervisory agencies. The existing organization was deemed adequate for insuring Air Corps control over military requirements and research policy and permitting the ultimate execution of scientific work by the designers and builders of experimental models. Such was the situation as to scientific coordination, a few months before the establishment by the White House of a Federal-wide National Defense Research Committee.

16. "Legislation Relating to the AAF Material Program, 1939-1944" (AAF Historical Studies No. 22, Nov. 1944), pp. 104-105; and NACA Executive Committee, minutes, 23 June 1939, p. 4, in AAF 400.112 NACA.
IV. PARTIAL RESEARCH AND DEVELOPMENT POLICIES, 1939-1944

Changing Military Requirements, 1939-1944

The Kilmer Board's 5-year program of June 1939, and its conservative modification by the Air Board in September 1939, continued into 1940 as Wright Field's immediate and long-term goals. A few additions to the program were added in December 1939 by the Air Corps Technical Committee, notably the Bombing-Through-Overcast problem, but they were not to be undertaken until the new fiscal year beginning July 1940. By the spring of 1940, however, the pressure was for the immediate rather than the ultimate improvement of Army aviation, chiefly for the rapid "modernization" of existing standard production models. British and German operations since September 1939 were showing the need for such aids as armor protection, leakproof tanks, turrets, radio equipment, and (for pursuits) droppable fuel tanks and auxiliary bomb racks. These needs, reported by military attachés, were underscored by the observations of Lt. Col. George C. Kenney while in England, and by a British Air Marshal's statement about April 1940, that "were the Army Air Corps to send its airplanes across into Germany today not one of them would return." General Arnold, impressed by these observations, ordered re-evaluation of the entire research program by a special board headed by Maj. Gen. Delos C. Emmons (commanding general of the CEC Air Force). Its first report, in May 1940, was devoted almost entirely to recommending the immediate or early installation of protective, defensive, and other auxiliary aids in the production models of bombers, pursuits, and transports. It added virtually nothing new to the airplane and equipment developmental objectives of 1939, except to revive barrage balloon development, which itself was another element in the defensive equipment. Furthermore, as England's strategic situation became worse, in the dark days of May and June 1940, the immediate production needs of the Air Corps became more and more pressing, and momentarily threatened the entire research program—the long-term goals as well as the immediate developmental objectives. Thus, on 7 May 1940, when the Germans were already

1. AEC minutes, 7 Dec. 1939, in A. J. Lynn project record book No. 15.
2. Other problems were: assisted take-off and landing devices, armor
   and bullet-proofing, and greater bomb capacity for pursuits.
   appointing Emmons president of the board to re-examine the Research
   and Development Program; copy in AFHIL.
   104...May 2, 1940," (2,38 pp., and tabs); copy in AFHIL.
In Norway but not yet in the Lowlands, General Arnold could still cable from Panama (where he was on a temporary mission) to urge that wartime research and development be vigorously pushed in the forthcoming defense of the budget estimates. Five weeks later, however, with British troops evacuated from Dunkirk and with France virtually conquered, the strategic situation had become so bad that Arnold ordered what was virtually a reversal, in favor of quantity production at all costs. Because of the "condition of world affairs and the will of the American people for adequate defense," he said, the first priority must be the "continuous production of current types of airplanes for the Army," while research and development must be given "the lower priority...consistent with the above/primary mission." Higher authority, probably including the White House and Congress, was involved in issuing this policy, and Arnold "personally" assured the Chief of Staff on 14 June 1940 that "every effort" was being made to standardize equipment, increase production, expedite deliveries, and "defer our present research and development program," and he hinted that some phases of the latter might even "be transferred to some other governmental agency," presumably referring to the new National Defense Research Committee. D-Day had been set at 1 October 1941 by the Chief of Staff, and the airplanes needed. Arnold stated, were "not those which will be produced four years from now, but those to be delivered within the next six months or a year, certainly not more than two years hence."

The research program was not scrapped, however. It was merely postponed temporarily, in specific cases where a manufacturer's production for the Air Corps would be interrupted by work on experimental contracts. The ten most important airplane projects were selected by thexerox Board (which had meanwhile been "educated" by an inspection trip to Wright Field), and priorities were assigned in June 1940, based both on strategic needs and on manufacturers' capacities for experimental work:

5. Memorandum for Chief, MD, by G/AC, 5 June 1940, in AAF 469.1-17 Aircraft--Manufacture of (U). Arnold had also verbally directed thexerox Board to this effect, "that research and development for the next six months, at least, will be subordinate to 'production'."
   Memorandum for Maj. M. E. Gross by Maj. B. W. Chidlaw, both in MD, 1- July 1940, in NAS file on "RAD Program, FY 1941."
1. 5,333-mile very heavy bomber (B-29, 30, 32)
2. 2-engine interceptor (Lockheed XP-49, Grumman XP-50)
3. 2,687 mile medium bomber (North American XB-15, 28A)
4. Escort fighter (Lockheed XP-56)
5. 1-engine interceptor (Vultee XP-64; Curtiss XP-55, Northrop XP-56)
6. Navy dive bomber
7. Light bomber (Martin XB-23)
8. Long-range bomber (3,000-mile range)
9. Observation airplane
10. 2-engine trainer (Beech AT-7A)

These priorities were not to be rigid, because of "the constantly changing military situation abroad," the capacity of the industry "to absorb...experimental development without interference with the approved procurement program," and the extent to which the current developmental projects were being successfully completed. In a few weeks the above priorities were revised, in the following rearranged order: 4, 6, 9, 1, 10, 2, 3, 5, 7, and 8.

The research program continued to be threatened by the production program, however. In September 1940 "certain aircraft manufacturers" complained to General Arnold that development projects were "taking the time of engineers who could be used to accelerate production of airplanes on the Expansion program," and he directed deferral of such projects (where production delays could be demonstrated) "until such time as airplane deliveries are up to schedule." At the same time the NACA laboratories were also affected; wind tunnels and other facilities were diverted from "basic research" in order to concentrate on improving the performance and correct the defects of current production models. By 1941 the stabilization of industry was well under way toward achievement, and experimental work could be resumed in more orderly fashion. The September 1940 policy was reversed, the aircraft industry was asked for its test programs for all experimental aircraft on contract, and the last major threat to the research and development during the war was removed.

9. Memorandum for Chief, MD, by C/AG, 12 Sept. 1940; referred to Wright Field as TI-342, 16 Sept. 1940; both in AAF 452.1-17 Airplanes, Manufacture of (O).
10. MD letter to all contractors, 8 May 1941, in AAF 400,112 Test, Development Work.
11. Ibid.
Research and development objectives continued to be affected, in 1940 and 1941, by British experience with the new and improved airplanes and equipment and tactics in the Anglo-German air war. In 1940, the turret and armament mission by Lt. Col. Grandison Gardner and Maj. F. O. Carroll, and the radar mission by Maj. A. W. Marriner (mentioned earlier), if they did not reveal actual gaps in the Air Corps research and development program, at least underscored the greater urgency of certain phases of material over others, and contributed suggestions as to more fruitful avenues of research. Certainly the work on turrets and radar detection and ranging were all prosecuted with greater vigor directly as a result of these Air Corps missions abroad. In the next year, the mission of General Arnold to London (in April-May 1941) likewise raised the priorities for high-altitude pressurizing, jet propulsion, controllable bombs, gliders, photography, and external fuel tanks for range extension, at the same time confirming Air Corps superiority of turbo-superchargers, camera installations, .50 caliber guns, bombsights, and air-cooled engines. After June 1941 refinements of the program were influenced by the Army's Special Observers Group headed by Maj. Gen. James E. Chaney (the Chaney mission, or SPOBS), even though this mission was preoccupied not with material but with tactical planning for future American participation with England in the air war against Germany. And later in 1941, Col. Ira C. Baker's observations in the United Kingdom covered a number of items of air materiel of great interest to Wright Field.

In addition to the influence of British tactical and experimental experience on Air Corps materiel development was the effect of the general strategic and political situation on the Air Corps program as a whole late in 1940 and in 1941, before America officially entered the

13. Many but not all of General Arnold's conversations and deliberations are described in his cablegrams from London to Washington, in AAF 311.22 Cablegrams (filed under 5 May 1941). See also Edward Warner to T. F. Wright, writing from London, 22 April 1941, in AAF 361.3 Lead-Lease Aid (filed under 15 June 1941); and NF to Chief, MG, telegraph, 13 June 1941 (copy), in MG file on "FY 1942 EAD Program."
14. Interview with a former member of SPOBS, Brig. Gen. H. M. McGlelland, ACO, about 9 Jan. 1945. The Air Technical Section of SPOBS, headed by Col. (later Brig. Gen.) A. J. Lyon, later was placed under ETOUSA, and after about Oct. 1942, was headed by Col. Howard, C. Bunker. A fuller discussion of this mission is included elsewhere in this study.
war. The research and development program of 1939, "thrown for a loss" early in 1940 by the immediate need for quantity production, gradually came back into full stature later in 1940. By 1941 the original program was fully revived and expanded. American development was being stimulated not only by specific ideas from Britain, but also by the changing strategic and political situation calling for closer collaboration with the Allies; the increasingly liberal policy of releasing advanced models to the British and other potential allies in March 1940; the establishment of the Army-Navy-British Aircraft Committee in September 1940 (later renamed the Joint Aircraft Committee); President Roosevelt's "fireside" announcement on 29 December 1940 that America would become the "arsenal of democracy," a concept applicable as much to development as to production; the Lend-Lease bill of January 1941, passed the following March; and the various war plans in preparation in 1941 for joint participation of American air forces with the British.

Coupled with this strategic situation was the Air Corps fear early in 1941 that Britain's own research establishments would suffer directly from military operations, if Germany's bombardment continued and if her plans for invading England were wholly or partially successful. In February 1941, for example, General Brett, in submitting about 80 additional developmental projects for General Arnold's approval, warned that the whole Air Corps developmental program had a new element of importance "because" the British program "has been greatly retarded" by the effect of operations on England herself. Similariy, one of the special observers in England early in 1941 (Maj. John G. Moore) was told by the British Ministry of Aircraft Production (Sir Henry Tizard, Director of Research and Development) that "from now on" Anglo-American research and development should be concentrated in the United States, "unhampered by enemy action," and that British technical personnel should be sent "to assist and to pass on such work as satisfying [British] requirements."

16. For all these steps in 1940 and 1941, see "Distribution of Air Material to the Allies, 1939-1944..." (AAF Historical Studies No. 11, July 1944).
17. APOC-1 plan, 27 March 1941; Atlantic Conference, 11-14 Aug. 1941; AWPD/1, 12 Aug. 1941; and Arcadia Conference, 23 Dec. 1941. AFOSI study, "Review of Aerial Warfare for the Scientific Advisory Board (Group)," Jan. 1945, pp. 15, 16, 17.
The Air Corps accepted the pressure of war in England as one more reason for expanding its own research organization. The British proposals to sit in on American research planning and administration were, however, not accepted, and became a problem of Anglo-American collaboration (discussed later) that was to vex all parties during the rest of the war long after the enemy occupation of England ceased to be an immediate threat.

After America officially entered the war in December 1941 the military requirements for new materiel continued to shift, properly, with changes in strategic and tactical plans, including greater emphasis on future needs in the Japanese theatres of war. The whole developmental program at Wright Field had grown to about 2,000 different projects by December 1941, "ranging in scope from a complete airplane down to an improved type of cowling." The special Kenney Board was asked in January 1942 to review the airplane development program and to recommend military characteristics for various types, including a 10,000 mile bomber and an "interim" long-range bomber with a range somewhere between the B-26 and the 10,000 mile bomber, showing the increasing preoccupation with the Japanese theaters of operations. The next month the 1942-43 program was set up and included estimates for two jet-propelled fighters (XP-59A), and for accelerated research with respect to "unconventional" engines, engines in the 4,000-5,000 horsepower class for use in very long range bombers, and controllable bomb and glide torpedoes. The whole story of changing military requirements cannot be treated in detail here, except to note that


22. A separate AAF Historical Study on the Military Requirements system is planned. See also daily diaries of Director of Military Requirements, March 1942-March 1943, and of AC/AS, Operations, Commitments, and Requirements, April 1943-date, both filed in AFPH. Requirements are or will also be treated in some detail in some twenty separate Historical Studies on specific categories of material, such as the Heavy Bomber, Radar and Radio Equipment, Aviation Gasoline and Lubricants, Armament, Bombing Equipment, Reconnaissance Airplanes and Photographic Equipment, and Power Plants, to mention only those in active preparation (as of March 1945). See also ATSC Historical Office "case histories" of selected, specific models of airplanes and equipment (154 currently projected); and the encyclopedic semi-annual status report of the ATSC, "Research and Development Projects," (latest ed., 1 Jan. 1945) filed in AFPH.
after December 1941 by far the greater increase came from America's own combat air forces, since the British, and that "theater requirements" came from both the European and Pacific areas, not excluding lesser but important theaters such as the anti-submarine campaign in the North Atlantic. By early 1942, of the total 1,700 items, the following were "design" or "operational projects" by General Mills and his immediate assistant Air Force.

**Classification**
- Aeronautical
- Ballistic-controlled bomb
- G-44 television, radio-controlled altitude bomb
- C-2 smoke-flare, television, radio-controlled GB
- Radar and television, radio-controlled G3
- T-35 overhead, radar-controlled bomb

**Air Bases**
- YP-30, XA-30, XR-30, XA-32, XA-33 bombers
- XP-55 and XP-56, XR-70, XR-75, X-70, XP-80 fighters

**Jet Engines**
- General Electric J-46, J6-40
- X-140 and later jet engines
- No Avarin M (M-15)
- Vultee V-1B
- Boeing J-34
- Vultee, Mercurjet, Centrujet

**Conventional Engines**
- Pratt and Whitney R-1830 (for XA-41, YC-39, XR-72, XB-36, XA-33)
- R-3350, improved (for XA-72 and XA-74)
- Allison V-1710 (for XA-72, XA-36, XA-194)
- R-1830-11 (YJ-143) (for XA-516, XA-614)

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27. Information for this, by Col. G. C. Miller, both in AAF, 7 Jan 1942, listing "operational projects" wanted by GC/AS, in 1941 a total of 1,700 items. The total figure of 1,700 projects is only a tentative in 1942 and 19,000 in July 1942. 1,700; the official Congressional "legislation and development projects" (7 Jan, 1942), which are not completed, listed only about 500.
Fuels
Grades 94/114 and 110/150 "super" fuel

Comming Gun Sights
E-1 (British Mark II C), for fighters
E-8 (Fairchild) and E-9, 10, and 11 (Sperry), for bomber turrets

20 mm fire control
General Electric, Sperry "local", and GE 4-gun upper forward turret

20 mm turrets
General Electric upper and lower remote, and remote tail
Martin and Emerson upper cylindrical types
Sperry tail (2 models, one 44")
Sperry nose and tail

Others
British flame thrower, airborne
Navy rocket, type 3, 25

Still other especially urgent projects were added during 1944, notably additional guided missile projects, inspired by the intensive use of robot bombs by the Germans after the Normandy invasion in June 1944.

As implied in the above sketch, the research and development programs derived from a system of "military requirements" at a higher echelon than Wright Field. During 1939-1941, before American entry into the war, this system was centralized in the Plans Section in the immediate office of the

24. The Plans Section of 1941, which dealt with both requirements and strategy, should not be confused with the later Operational Plans Division (March 1942 to March 1943) and AG/AS Plans (April 1943—date). The latter offices normally did not formulate either quantity or quality requirements. Occasionally their diaries revealed that they commented on staff studies and R&D's from Requirements or Materiel, and now and then provided them in behalf of particular projects, such as glide bombs (1942) and rescue equipment (1943).
Chief of the Air Corps, supplemented by a committee usually representing OCA
corporate headquarters, the tactical arm (the USAF Air Force, established in
1935), the General Staff, and the Materiel Division. This committee,
which was known as the Air Corps Technical Committee between 1930 and
1936, was apparently abandoned after its last meeting in December 1933,
being fundamentally in part by such ad hoc agencies as the Hilmar
Board in March 1939 and, later, the Munos Board in May and June 1940.
The committee system was under attack both within and outside the Materiel
Division, and in June 1940 assurance was given at the top that there
would be "no more special boards" that might provoke contradictory direct-
ives.25

In 1942 the requirements function was reorganized into the Directorate
of Military Requirements and its various subordinate "type" directorates
for Bombardment, Air Defense, Air Support, etc., and this system was again
reorganized in March 1943 into the Requirements Division of the AC/AS
Operations, Commitments, and Requirements (OCAR). The exact division of
labor between the Requirements project officers and the Materiel project
officers was occasionally not clear. The usual stereotyped division of
labor, formalized in an OCAR directive addressed to its own requirements
officers in April 1943, was that OCAR "formulates and transmits to the
Materiel [Command] necessary military requirements... upon which... Materiel... can base its development, production, and procurement," while the Materiel
Division in AC/AS "supervises the development, procurement, and production
of aircraft, equipment, and supplies...[by] the Materiel Command."26
OCAR officers occasionally went beyond prescribing "what is wanted" to
direct "how" the directive was to be carried out by Materiel. Their
frequent contacts with project officers at Wright Field, although "informal,"
occasionally led to contradictory policies being imposed on the latter;
and their visits to contractors' plants were occasionally made without
direct authorization by Wright Field. These and other deviations from

informal conference including Gen. Arnold, Gen. Bragg, Col. Nichols,
and others on 16 June; in NAS file on "FT 1941 MAD Program."
26. OCAR 0, W. No. 9, 22 April 1943, in NAS file "18,100 Miss—Gen. 8.
This directive is similar to the one issued a year earlier, shortly
after the Directorate of Military Requirements was established in
March 1942. See DMR 0, W. No. 9, 17 March 1942, in AAF 300, 6 OCA
[sic] Munos, Numbered (U). See also DMR 0, W. No. 12, 26 March 1942,
and No. 13, 26 March 1942, both in Ibid.
prescribed procedure were not infrequent, and apparently were
welcomed wherever the staff officers concerned were made aware of
Cross, his chief of requirements, attempted to reconcile informal
directness and formal channel by means of an office order in April
1944 on the subject of industrial liaison, that "one project officer
shall make no commitments, give no instructions, and make no state-
ments to manufacturers which, in any way, might be construed as
approval by this headquarters of anything being done by the manufacturers
or contemplated by them."

In October 1944, when plans for the re-
organization of the entire AAF Headquarters were again under way, the
problem of material vs. requirements was again aired, but neither
staff officer apparently submitted a drastic recommendation, and the
plan called for no reorganization of development and requirements
functions. Requirements merely observed that "extreme care is
now being exercised to insure that in the future this [interference
of requirements with internal] supervision of the development program
will not happen;" and recommended that in the case of AES and ATC be
given more experienced personnel to make unnecessary the occasional
decisions from normal chains by requirements officers who were
more intimately familiar with a given project. 26

Just recently, the requirements system but indirectly (through the
AAF Board) remained under "CIA was the work of the AAF Equipment Board
at Col. G. T. G. D. established about January 1943 in order (among other
things) to handle the problem of liaison with various theaters,
study of different conditions, and the establishing of military character-
istics for various items of air equipment. 27

27. For samples of complaints, see memorandum from Wright Field (Lt. Col.
D. N. Tew), 18 March 1943, in AAF 3813, or projects; minutes of
Director's Conference, 29 June, 27 Aug., 1942, in AAF 337
Conference, "CIA" Committee Minutes, Major T. Jan.,
1939, and 30 March, 29 Sept., 1944; and memoranda for Col. J. P.
Candia, May 6, 1943, and in AES 3, 11 Aug., 1944, in AES file
"100 Misc. -- Gen."

28. Minutes of "All staff meeting, 1 April 1944, in "CIA"
Material Division file of staff-meeting minutes.

Office Administration (filed under 3 Nov., 1944).

30. Act 1025, "CIA" Requirements Division to 10/STC, 17 Nov., 1944, in AIB.

31. Memorandum for "Director of Base Services (Col. I. M. H. H.)" by
Chief of Staff (Col. R. F. Childlaw), Material Command, 22 Jan.
1947, in AES file "100 Misc. -- Gen."
Childlaw and Wright Field
officers had discussed the work of the new board with Col. McGregor,
proposed head of the board.
Presumably items developed and procured by non-AFP supply services of the Army were to be more closely followed, although its testing activities covered items developed by Wright Field's Equipment Laboratory as well.

Ultimately there perhaps was no workable alternative for close collaboration between the planners of research (Requirements) and the supervisors and monitors of research (Material), whether the collaboration was to take place in formal committees or in informal day-to-day contact. The committee system, presumably abandoned in 1940, was actually revived from time to time under assumed names. The AAF Material Planning Council, set up in July 1942 with members from the Directorates and from Material Command headquarters, while it was preoccupied with the fuller "utilization of production capacities," also attempted "to exercise close control over Research and Development," and for a few months reviewed particularly the modification program by which new and improved devices were being incorporated into existing standard material. This Council apparently expired before the end of 1942. In 1943 and 1944 still another use of committees was made, in this instance for the periodic review of Wright Field projects jointly by SWAD and OCAR. By means of formal sessions in 1943 and 1944 they attempted to eliminate projects of marginal value "which are not paying their freight," to re-group priorities in accordance with changing tactical demands, and to provide the "educational" benefit to project officers at all echelons afforded by brief oral descriptions of each project, its status, and its potential value. The review late in 1944 was to be made in accordance with the AAF Material Demobilization Plan of 23 September 1944 and "Project B-M," for post-war research, and called for re-groupings of priorities as follows: (A) projects which have an intrinsic value for use against Japan; (B) projects which can be completed within 18 months after Germany's surrender; (C) projects of sufficient importance to be classed as "long-range, continuing military developments;" (D) projects in the "suspense category;" and (E) projects which should be terminated.


33. Other staff offices also were represented, including the M&IS's and Training. NWAS Material Division, diary, 21 March, 5, 7, 21 April 1944; and correspondence in AAF 380 Programs and Projects (April-May, and Oct. 1944.)

34. A&IS NWAS Daily activity report, 4 Oct. 1944. The "D-7" postwar plan, covering the fiscal years 1946-50, was prepared about Aug. 1944.
The circulation of ideas or the revival of old ideas useful for application to aerial weapons could not always be rigidly channeled, however, and officers and civilians other than those in the Requirements-Material administrative sequence were involved in deviations from this simple organizational pattern. Most prominent, and concerned particularly with radar, was the Air Communications Office, established in December 1941 under a different name, and the special group of "expert civilian consultants," established in April 1942 under Dr. Edward L. Bowles to serve both the War Department at large (through the Secretary of War) and the AAF in particular (through General Arnold). Dr. Bowles concerned himself with both developmental and tactical phases of radar, and his group attempted to get the civilian scientist in closer touch with the military strategist, and to forward the thesis that radar and other electronics aids must be recognized in "overall strategic planning in its early stages," instead of leaving the radar scientists and engineers "engrossed in the physical devices themselves," on the one hand, and the strategists concerned with their specialties, on the other hand.36

Another administrative device to encourage new ideas was the "wishful thinking committee," tried out experimentally in the summer of 1944 in the Air Staff. This "Informal Committee on AAF Development," as it was formally called, was proposed in June 1944, apparently by OCAD, and was intended to represent not only OCAD and MOAD but also other Air Staff offices, including the Air Communications Officer, the AG/AS for Intelligence, as well as officials technically outside the Air Staff, such as Dr. Bowles and the President of the AAF Board at Orlando, Fl. Among the problems of future research, items such as the following were discussed, informally and without minutes: aircraft-launched rockets, robot bombers, fire control, and night photography.35 Its discussions

35. See drafts of Historical Division studies on "Radar and Radio Equipment" and "Communications Techniques" for discussions on the relationship of ACO to material requirements.
37. See inter-office correspondence on this committee, 23-27 June 1944, in AAF 354 Board... Misc.
38. Memorandum for committee members by AG/AS OC&AR, 6 July 1944, in NAS file 30,105 "New Developments Division." Numerous suggestions for discussion by the Committee, assembled from the various project officers in NAS by Col. R. C. Wilson, July - Aug., 1944 (filed in NAS file #30,109 Committee on AAF Development?), pertain to engines, fuel systems, propellers, armament, guided missiles, photography, and navigation aids.
were currently "abandoned" by September 1941. Toward the close of the year another committee was established, this time a group of civilian consultants known as the "Scientific Advisory Group", headed by Dr. Theodore von Kármán, and attached to the immediate office of the Chief of the Air Staff. Among its duties this group was directed to assemble here for new research, possibly of the "black art" variety, for use during this war or for post-war development. Such ideas may be impractical now, but at least as not opposed to a true line of science, they demonstrate utility for future research, such as improved rockets, methods of remote control, countermeasures, etc. 39

One of its studies, in March 1945, concerned long-range, ... rockets, rocket-actuated guided missiles of the V-2 type, both unmanned and manned. 40

The ideas and proposals from all these and other sources were passed to General Arnold's demand, voiced in his staff talks on the new Continental Air Force, that the Air Staff and MA Headquarters must continue to look forward, that staff officers must be alert to new ideas, even to the extent of questioning specific aspects of current aerial development, current tactics, and current strategic plans. Ideas from all sources were to be encouraged. Whether, then, and how the new to be translated into changes in "military requirements" and "needs in the research and development program" remained, however, as counsel of the staff officer concerned directly with these issues,

**Aeronautical Laboratories, 1932-1934**

The expansion of the aerodynamics and engine research facilities of the Air Force basic to the prosecution of the Air Force's development program, and after 1930 there was little resistance by Congress or the Army to the financing of "Aeronautical activities."

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39. "In Minutes of Staff Meeting of 169, 19 Feb., 1945, in 15TH.
40. 13TH: 1 June 1945, daily activity report, 12 March 1945, in 15TH. OMA recommended that the Scientific Advisory Group prepare the military characteristics of the V-1 and V-2 and other possible long range missiles.

1. Ten "Correlation and Evaluation of the AAF Aeronautical Program, 1939-1944" (AF Historical Studies No. 72, Nov. 1944), pp. 102-121.
The entire budget of the NACA for the five fiscal years 1940–44 ultimately totalled almost $100,000,000, divided by fiscal years as follows:2

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>$4,374,546</td>
</tr>
<tr>
<td>1941</td>
<td>11,200,000</td>
</tr>
<tr>
<td>1942</td>
<td>19,865,910</td>
</tr>
<tr>
<td>1943</td>
<td>28,428,736</td>
</tr>
<tr>
<td>1944</td>
<td>38,392,215</td>
</tr>
</tbody>
</table>

The expenditures of this unprecedented budget, which was about six times the total spent between 1919 and 1939, was distributed as follows:

A large portion of these expenditures went for the new wind tunnels and other laboratory facilities, first at Langley Field, next (1940) at the new Ames Aeronautical Laboratory at Moffett Field, Calif., and finally (1942) at the new Engine Research Laboratory at Cleveland. By 1945 the NACA's $370,000,000 plant contained 38 wind tunnels, including the mammoth 80-foot tunnel for full-scale airplanes at Ames, perhaps the largest and most costly piece of scientific apparatus in the world; a 1,300-mph supersonic tunnel; and two special tunnels at Cleveland for engine testing—an altitude tunnel and an icing research tunnel. Although there were also many tunnels outside the NACA—27 at engineering schools, 10 at aircraft manufacturers, and 4 each at the Army and the Navy establishments—none of them were as large, versatile, and as highly specialized as the equipment of the NACA. Only the Federal Government could undertake the construction of such equipment and make it available to industry and the military as a "community service."

The NACA's personnel strength likewise grew from 576 in July 1939 to 1,793 in January 1942 and 6,252 in February 1945. In terms of professional categories, the distribution of employees was as follows (as of 1944): 29% engineers, pilots, physicists, mathematicians, chemists, etc.; 38% scientific aids, computers, laboratory assistants, draftsmen, mechanics, tool-makers, pattern-makers, etc.; and 33% clerical and other non-professional workers.

4. The NACA also had an "Ice research center" at Minneapolis in 1942. Mentioned in AAF 4521 Assignment (6 Oct. 1942).
6. Figures received by telephone from NACA Personnel Office, 22 March 1945.
The wartime expansion of the NACA normally had the approval and support of the AAF. This support usually took the form of defending NACA budgets before the Budget Bureau and Congress, appealing to the War Production Board for preference ratings for materials and equipment wanted by the NACA, seeking a more liberal draft deferment policy for the younger technical men employed by the NACA, and supplying the NACA with aviation fuel and lubricants. In some cases, however, the NACA was in competition with the AAF for men and materials, and 100% support by the AAF was denied. Thus, in July 1944, NMAAD criticized NACA for seeking White House support for the very highest WTB priority for jet propulsion test facilities, at the expense of the work of the AAF on fuel injection "and other must projects", although earlier (in May) the AAF had supported the NACA in getting what it regarded as adequate priorities for the construction of a supersonic wind tunnel. Similarly in August 1944, NAS (successor to NMAAD) non-concurred in an NACA proposal to seek 1,000 additional civilians through the Civil Service Commission, because the "only source" for such employees would be the AAF—the Material and Air Service Commands.\footnote{Minutes of NAS staff meeting, 15 July 1944, in NAS Development Engineering Branch file on "staff meetings"; NMAAD Material Division, diary, 31 May 1944; and joint letter to WTB by Gen. H. H. Arnold, Adm. E. J. King, and Gen. J. C. Marshall, 26 May 1944 (copy), in NAS file "700.260 NACA."}

\footnote{Minutes of NAS staff meeting, 26 Aug. 1944, in NAS Development Engineering Branch file on "staff meetings".}
Expansion of AAF Experimental Facilities, 1939-1944

The tremendous wartime expansion of the research budgets for the AAF between 1939 and 1945 is shown in this tabulation, by fiscal years:

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>$3,574,290</td>
</tr>
<tr>
<td>1940</td>
<td>15,000,000</td>
</tr>
<tr>
<td>1941</td>
<td>102,231,275</td>
</tr>
<tr>
<td>1942</td>
<td>98,198,615</td>
</tr>
<tr>
<td>1943</td>
<td>113,342,636</td>
</tr>
<tr>
<td>1944</td>
<td>121,647,505</td>
</tr>
<tr>
<td>1945</td>
<td></td>
</tr>
</tbody>
</table>

These figures are conservative because they exclude general funds such as officer pay, but they do show the trend. Expenditures by the various Wright Field laboratories and by their industrial and other contractors were as follows, listed under the three budgetary "projects" of Experimental, Civilian Payroll, and Service Test:


2. Tabulated from 1st Ind. (basis unknown), AAF Hqs. (WMD) to Director, Budget Division, OS/8, no date, about Oct. 1943, in W&G file "700.430... Kilgore Committee."
<table>
<thead>
<tr>
<th></th>
<th>FY 1950</th>
<th>FY 1951</th>
<th>FY 1952</th>
<th>FY 1953</th>
<th>FY 1954 (est.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief &amp; Technical Staff</td>
<td>95,120</td>
<td>103,723</td>
<td>112,000</td>
<td>120,000</td>
<td>127,480</td>
</tr>
<tr>
<td>Aeronautical Lab.</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
</tr>
<tr>
<td>Aircraft Lab.</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
</tr>
<tr>
<td>Aircraft Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Mechanical Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Materials Lab.</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
</tr>
<tr>
<td>Propulsion Lab.</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
</tr>
<tr>
<td>Engineering Service</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Total</td>
<td>188,040</td>
<td>203,723</td>
<td>222,000</td>
<td>242,000</td>
<td>267,480</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FY 1951</th>
<th>FY 1952</th>
<th>FY 1953</th>
<th>FY 1954 (est.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief &amp; Technical Staff</td>
<td>95,120</td>
<td>103,723</td>
<td>112,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Aeronautical Lab.</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
</tr>
<tr>
<td>Aircraft Lab.</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
</tr>
<tr>
<td>Aircraft Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Mechanical Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Materials Lab.</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
</tr>
<tr>
<td>Propulsion Lab.</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
</tr>
<tr>
<td>Engineering Service</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Total</td>
<td>188,040</td>
<td>203,723</td>
<td>222,000</td>
<td>242,000</td>
</tr>
</tbody>
</table>

**Civilian Payroll for Research and Development, 1952-54**

**Civilian Payroll for Research and Development, 1952-54 (est.)**

<table>
<thead>
<tr>
<th></th>
<th>FY 1951</th>
<th>FY 1952</th>
<th>FY 1953</th>
<th>FY 1954 (est.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief &amp; Technical Staff</td>
<td>95,120</td>
<td>103,723</td>
<td>112,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Aeronautical Lab.</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
<td>33,980</td>
</tr>
<tr>
<td>Aircraft Lab.</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
<td>25,840</td>
</tr>
<tr>
<td>Aircraft Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Mechanical Eng. Lab.</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
<td>27,900</td>
</tr>
<tr>
<td>Materials Lab.</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
<td>10,800</td>
</tr>
<tr>
<td>Propulsion Lab.</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
<td>28,200</td>
</tr>
<tr>
<td>Engineering Service</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Total</td>
<td>188,040</td>
<td>203,723</td>
<td>222,000</td>
<td>242,000</td>
</tr>
</tbody>
</table>
In terms of civilian and military personnel at Wright Field the following was the situation during the war years 1939-43 for all material activities, both experimental and production:

<table>
<thead>
<tr>
<th></th>
<th>Civilian</th>
<th>Officers</th>
<th>Enlisted Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 July 1939</td>
<td>1,759</td>
<td>149</td>
<td>76</td>
</tr>
<tr>
<td>1 July 1940</td>
<td>2,476</td>
<td>225</td>
<td>104</td>
</tr>
<tr>
<td>1 July 1941</td>
<td>4,341</td>
<td>233</td>
<td>83</td>
</tr>
<tr>
<td>1 July 1942</td>
<td>10,903</td>
<td>1,220</td>
<td>479</td>
</tr>
<tr>
<td>1 July 1943</td>
<td>10,412</td>
<td>1,718</td>
<td>5,146</td>
</tr>
</tbody>
</table>

What percentage of this staff was engaged on research and development projects is not known for these years; perhaps at least a third is a conservative estimate. In 1944 more precise figures are available, revealing 5,976 persons engaged in research and development activities, divided as follows:

<table>
<thead>
<tr>
<th></th>
<th>Civilian</th>
<th>Officers</th>
<th>Enlisted Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directors or supervisors</td>
<td>181</td>
<td>268</td>
<td>3</td>
</tr>
<tr>
<td>Professional research workers</td>
<td>604</td>
<td>799</td>
<td>56</td>
</tr>
<tr>
<td>Laboratory and Mechanical Assistants</td>
<td>1,494</td>
<td>1,975</td>
<td>128</td>
</tr>
<tr>
<td>Legal, technical, and others</td>
<td>654</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

While only 20 to 25% of these were "directly involved in creative applied research work," all of them were engaged in "any endeavor leading to the improvement of the quality of production equipment and changes to meet the requirements of the ever changing needs of the theaters of operation." In addition, the Washington offices (AC/AS, NAM) included 22 officers and 21 civilians "directly engaged in supervisory control of the Research and Development Program."4

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4. NAMD, "Army Air Forces Research and Development Program," 19 pp., no date, about April 1944, in NAM file "700,430 ... Kilgore...."
Experimental facilities were likewise expanded, perhaps tenfold between 1939 and 1944. In terms of capital investment, Wright Field's plant grew from 10 millions in 1939, to 35 millions in December 1941, to nearly 54 millions in April 1944, financed partly from the Research and Development budgets (listed above) and partly from the separate budgets for Construction. The AAF, relatively starved for funds for expansion during the years of peace before the war, prudently seized the war opportunity to build up its permanent facilities for future use against the day when appropriations again might be difficult to obtain. The investment was about evenly divided between laboratory structures and technical equipment, and was distributed among the various laboratories as follows (as of April 1944)\(^5\):

**Capital Value of Wright Field Technical Facilities, 1944**

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Laboratory Structures</th>
<th>Technical Equipment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero Medical</td>
<td>370,000</td>
<td>200,000</td>
<td>470,000</td>
</tr>
<tr>
<td>Aircraft</td>
<td>6,100,000</td>
<td>5,100,000</td>
<td>11,200,000</td>
</tr>
<tr>
<td>Aircraft Radio</td>
<td>2,000,000</td>
<td>6,140,000</td>
<td>8,140,000</td>
</tr>
<tr>
<td>Armament</td>
<td>1,300,000</td>
<td>300,000</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Engineering Shops</td>
<td>2,000,000</td>
<td>1,030,000</td>
<td>3,030,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>1,300,000</td>
<td>1,500,000</td>
<td>3,800,000</td>
</tr>
<tr>
<td>Flight Section</td>
<td>5,300,000</td>
<td>250,000</td>
<td>5,550,000</td>
</tr>
<tr>
<td>Materials</td>
<td>700,000</td>
<td>600,000</td>
<td>1,300,000</td>
</tr>
<tr>
<td>Photographic</td>
<td>200,000</td>
<td>800,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Power Plant</td>
<td>6,100,000</td>
<td>7,300,000</td>
<td>13,400,000</td>
</tr>
<tr>
<td>Propeller</td>
<td>2,400,000</td>
<td>2,200,000</td>
<td>4,600,000</td>
</tr>
<tr>
<td>Technical Data</td>
<td>300,000</td>
<td>400,000</td>
<td>700,000</td>
</tr>
</tbody>
</table>

28,470,000 25,770,000 53,740,000

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5. Statement by Brig. Gen. O. P. Nichols, in *Flying*, Dec. 1941, p. 82; and "AAF B&G Program", 19 pp., no date, about April 1944, in HGS file "700.420 Kilgore...".

6. Ibid.
Among the outstanding facilities were the following, spread across the changing map of Wright Field: Aircraft Laboratory; wind tunnels, both vertical and horizontal, for tests at various simulated altitudes and at supersonic speeds; structures test equipment; design and mock-up facilities for scale construction; engineering, vibration, and other equipment to determine suitability of aerodynamics, structural, vibration, and flutter characteristics. Aero-Medical Laboratory: altitude chambers; all-weather room; centrifuge equipment; animal-research quarters. Armament Laboratory: armament firing and calibration rooms; gun ranges; altitude chambers. Equipment Laboratory: electrical test units, including test unit for very high electrical loads, instrument test equipment; fireproof room; all-weather room. Flight Section: special concrete runways, including accelerated runways; hangars; fuel systems. Materials Laboratory: chemistry and physics laboratories; tensile and other structural test equipment; cold rooms; X-ray rooms. Photographic Laboratory: dark rooms; camera workshops; cold room. Power Plant Laboratory: engine test stands; jet propulsion test stand; dynamometers; fuel test equipment; torque stands; supercharging rooms; calibration room; altitude equipment; cold and tropical weather rooms. Propeller Laboratory: propeller test whirl rigs; torque stands; vibration rooms.

Outside of Wright Field were several additional facilities under the jurisdiction of the same command, including the guided missiles test site at Muroc Dry Lake, Calif., established in 1941; the glider test field at Wilmington, Ohio, about 1942; racks for "exposure durability tests" of casings, plastic, and other materials at the Homestead (Fla.) Air Base, about 1945; and the rocket test base at Dover, Del., 1944.

A further expansion of the Materiel Command's experimental establishment was in the field of radio and radar equipment, which until October 1944 was outside the direct control of the AAF and under the jurisdiction of the Signal Corps. After a long struggle between the two procurement services, General Marshall approved the transfer of airborne radio and radar activities to the AAF, stating that he was "increasingly impressed" that "the design and operation of aircraft is becoming more and more inseparably associated with radio and radar development", and that the latter must be

7. Ibid. See also "Master Plan" of Wright Field in AAF/Army Installations Division; and various aerial photographs of Wright Field over the years 1925-45, in Materiel Command Historical Office, "History of the Materiel Command, 1920-41", appendix.
8. The long history of Air Corps-Signal Corps relations cannot be recapitulated here. For a brief discussion, see "The Development of Radio and Radar Equipment for Air Operations, 1939-1944" (AAF Historical Studies No. , draft, Aug. 1944).
treated ... as a part of the main problem of aircraft design and operation rather than as accessories. In this shift the AAF inherited the Signal Corps facilities at Wright Field (chiefly the Aircraft Radio Laboratory, built up over many years adjacent to the Air Corps laboratories), together with an estimated 195 officers, 170 enlisted men, and 1,470 civilians; the field laboratories at Boca Raton (Fla.), Florosa (Fla.), and Indianapolis; and a field station at Clermont, Fla. Further expansion was planned by the AAF after the transfer was effected in October 1944. The Research and Development budget estimates for radio and radar work were expanded, and additional facilities were foreseen. In this direction the AAS in April 1945 proposed "an experimental airway and associated fields to serve as a field laboratory for the study of air navigation and traffic control," toward the goal of all-weather combat and training flying."

Another expanded element of Wright Field's experimental establishment was the guided missiles activity, administratively buried under the innocuous name of "Special Weapons." Ever since 1940 Wright Field had a portion of its budget allotted to remote-control bombs, and in about October 1941 General Arnold directed an expansion of the air base at Muroc Dry Lake, Calif., including a permanent detachment there for the testing of glide bombs, the "aerial torpedo," and controlled wing bombs. The Materiel organization, and the AAF as a whole, were preoccupied with other more urgent development projects in 1942 and 1943. At the same time the Muroc test site was expanded and a number of projects were under way both in the AAF and the Signal Corps, and Materiel officers were aware, like the chief of the Armament Section in Washington in March 1943, that it was "unwise ... from both the technical and political angle ... to inadequately recognize the possibilities that lie in developments of this nature."

9. Memorandum for Generals Arnold (AAF) and Somervell (ASP) by G/S, 26 July 1944 (photostat), in NAS file "30.105 New Developments Division."
10. Ibid.
11. AG/A9, OCMR, daily activity report, 8-9 April 1945.
13. Memorandum for AG/S-2, Materiel Command Msgs, by Col. W. H. Joiner, 8 March 1943, in AAF 380 Programs and Projects. Joiner urged more collaboration with the Naval Research Laboratory, the NRC Radiation Laboratory, and three firms—Fairchild, Douglas, and Interstate.
In June 1944 guided missile development was given a new impetus by the spectacular use of robot bombs by the Germans, together with a growing interest in guided missiles on the part of the senior air commanders overseas. The expansion of the Special Weapons Unit at Wright Field was approved by General Arnold on 11 July, calling for about 250 extra personnel and additional construction at Wright Field and at the Marcel Air Base; and in September, military characteristics for various new missiles were established as the basis for the future development program. 14 Involved also was the problem of whether the AAF would achieve full jurisdiction over the program, in both its tactical and material phases. The Army Ground Forces, the Army Service Forces, and Ordnance all were interested in controlling development of these missiles that were "ground launched"; the AAF was interested not only in "aerodynamic" missiles but also in any that were to be used in strategic bombing; and the Signal Corps was involved, since most of the missiles would use radio or radar controls. The problem of the Signal Corps was settled when its entire air-related responsibilities were shifted to the AAF in August, and the air-vs.-ground controversy was arbitrated by the General Staff in September 1944, as follows: The AAF to develop all air-launched missiles, and all aerodynamic missiles regardless of how launched; the AAF to develop all ground-launched "momentum" missiles, with military characteristics coordinated by Army Ground Forces; and in either case, "ultimate tactical employment" not to be exclusively determined until development progressed further. This division of responsibility applied likewise to the development of propulsion units (ram-jets, rocket, or "more conventional means") and control systems (mechanical, radio, radar, television, or infra-red); but war heads, non-integral launching devices, ground components of control systems each would be handled by that Army procurement service that had "the basic technical ability in research", presumably the Ordnance Department and the Signal Corps. 15 It was a "compromise" agreement

14. WMA D Material Division, diary, 36, 30 June, 10, 12 July 1944; memorandum for G/AS, by WMA D, about 11 July 1944, in AAF 330 Programs and Projects; and memorandum for Ordnance Department by G/AS (written by Col. F. H. Richardson, WMA D), 7 Sept. 1944, in AAF 360.2 Development and Research.

15. AC/AS AAS, daily activity report, 14, 19 Sept., 10, 15 Oct. 1944
between tactical commands and between procurement services, according to the Chief of the G8AIR Requirements Division:

It is probably not the best that could be done, but nevertheless, it is one of which complete agreement was possible at this time. ... Perhaps the best way for the Army Air Forces to gain and hold control is to initiate and continuously execute a vigorous program so that we will always be a step or two ahead. ①6

Expansion of AAF Service Test Facilities, 1932-1944

Before World War I service and tactical tests of airplanes and equipment were a joint function of the material center at Wright Field and of the tactical arm (the GEQ Air Force), a modification of the general theory that final evaluation of a product and its tactical application should be out of the hands of those who had engineered or supervised the development. During the two decades of peace 1920-40 this activity, on a very small scale, was located at Wilber Wright Field (renamed Patterson Field in 1931), and in the very early years included Maj. H. W. Schroeder’s "testing and proving squadron," about 1918-21. In 1937, after the GEQ Air Force was established (in 1936) as the tactical air arm, the latter supplied a detachment at Patterson Field for service tests, apparently in accordance with a recommendation of the Hymen Board in favor of Patterson Field, to permit the test detachment to take "full advantage of the engineering facilities at nearby/ Wright Field and the repair facilities at Patterson Field, and ... permit the engineers at / both/ Fields to be in constant touch with the tests." The testing activities continued in 1941, under the reorganized Air Force Combat Command, and the test


1. Recommendation of the Hymen Board, 22 July 1935, in AG 600 (4-6-35), sec. 1. For GEQ AF progress reports on service tests, 1935 - Aug. 1940, see AAF 400.112 Status of Service Tests Being Conducted by GEQ, "Special File" (U). See also AAF 400.112 Fairfield Service Tests (March 1921-Sept. 1942) (U).
detachments normally consisted of two combat crews per airplane. Meanwhile in the fall of 1939 the armament phases of service testing began to be shifted to Eglin Field, Fla., and control shifted from the ORG Air Forces to the Air Corps Board and its recently-organized 23rd Composite Group. The site of Eglin Field had been selected in April 1939 by Air Corps and Ordnance officers because of its suitability for studying "fire control" and ballistic 'problems," and the site was regarded as superior to any of the Army's reservations elsewhere in the United States, including Wright Field, Aberdeen Proving Ground, Ossona (Mich.), and others. By November 1939 the 23rd Composite Group was conducting its first armament tests there, involving the F-26B and N and the WP-37; and in August 1940 it began its first bombardment tests. Only armament and air ordnance tests were under consideration when the site was originally selected, and even as late as May 1941, when Eglin Field and the 23rd Composite Group were reorganized into the "Air Corps Proving Ground," the new directive defined the testing mission only in terms of "tactical tests of aircraft armament and its accessory equipment."

Furthermore, the appointment of one of the Material Division's top-ranking armament officers (Gen. Grandison Gardner) to head the organization in 1941 emphasized Eglin Field's armament

2. Memorandum for G/AAF by G/AC, 25 July 1941, in AAF 400.113 Tests and Experiments (U), (filed under 11 Sept. 1941). Exactly when service testing at Patterson Field was abandoned is not known. Various proposals were made for retaining the work there, including a plan by J. W. Fiala of the Material Division in Aug. 1940. See MB, Chief, MD, to Plans, 10 Aug. 1940, in AAF 400.113 Tests and Experiments (U).

3. The discussion in this and following paragraphs is summarized, except where otherwise noted, from data selected from Proving Ground Command Historical Branch, "Historical Outline of the Proving Ground Command" (Jan. 1945), especially pt. 1, pp. v, viii, 16, 20, 22, 31-32, 40, 44-65; and pt. 2, appendix A, exhibits 5, 6.

mission; and in general there was an awareness in the Air Corps that armament was the biggest gap in the testing program. At the same time, however, ever since November 1939, the 23rd Composite Group had undertaken some non-armament tests, and by the end of 1941 more than half of its projects were outside the field of armament. Ultimately the more inclusive function covering all air material was acknowledged when the Proving Ground was reorganized into an AAF Command in April 1942. More than half of the nearly 1,500 test projects undertaken at Eglin Field between late 1939 and February 1945 have been concerned with the operational suitability of aircraft and of air equipment other than armament and ordnance.

5. The need for an armament proving ground was underscored in April 1941 by one of the Air Corps observers in England (Maj. John G. Moore), who recommended (based presumably on his observations in England) an "Aircraft Armament Proving Ground" devoted "solely" to that specialty, "entirely divorced from other activities", and manned by Air Corps and Ordnance personnel. See Moore's final report to G-2, 11 April 1941, in Air Intelligence Library, "U.S. - 2545." The Materiel Division (Lt. Col. F. D. Carroll, Chief of EES) likewise dealt entirely with armament in "urging" such a Proving Ground in a study on 26 April 1941; and the Air Force Combat Command (Brig. Gen. C. W. Russell) concurred in the proposal on 12 July 1941. See Materiel Command hqs. file on "CYI-190."

6. Most of the 23rd Composite Group's test reports, progress reports, and related correspondence of OCAC headquarters in 1940 are filed in AAF 400.112 Test, Development Work, and in AAF 400.112 "Bulk" files.

7. See Proving Ground Command Historical Branch, "Index and List of Service Tests Activated at Eglin Field (1939-28 Feb. 1945)", 2 vols., 142, 100 pp., in AFIHL. This valuable reference manual is a cumulative historical list of all PGC tests on airplanes and other materiel, 1939-45, showing test number, title of test, completion date or other disposition; arranged according to category of material or operational techniques; and supplemented by an exhaustive analytical index to specific materiel nomenclature, cooperating or other related agencies (e.g. Materiel Command, Navy, MDRC, British, manufacturers), and some tactical and other subjects.
The wartime expansion of facilities for "operational suitability" tests at Eglin Field was comparable in extent to the expansion at Wright Field. In October 1940 the field itself was vastly enlarged by the acquisition of the Choctawhatchee National Forest adjoining Eglin Field, followed by the construction of special runways and several auxiliary fields and the building of special hangars, laboratories, and administrative buildings on the reservation. In terms of funds, the allocations to undertake this construction were as follows, by calendar years:

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1941</td>
<td>$4,742,936</td>
</tr>
<tr>
<td>1942</td>
<td>$4,492,769</td>
</tr>
<tr>
<td>1943</td>
<td>$2,456,300</td>
</tr>
<tr>
<td>1944</td>
<td>$2,234,475 (to 30 June only)</td>
</tr>
</tbody>
</table>

In addition to its facilities at Eglin Field, the Proving Ground Command was also given jurisdiction over the Cold Weather Test Detachment and its facilities at Ladd Field, Alaska, in August 1942; and a special climatic hangar at Eglin Field was under construction late in 1942. In October 1943 PGC detachments were also established at the Ordnance and Chemical Warfare proving grounds at Aberdeen (Md.), Edgewood (Md.), Jefferson (Madison, Ind.), and Southwestern (Hope, Ark.); and later, detachments were assigned to other similar installations.

Still another group of service testing facilities established during the war were those belonging to the tactical development organizations set up at Orlando, Fla., beginning in 1942. The Air Defense Board (about March 1942) and the School of Applied

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8. A separate historical study on the facilities of the Proving Ground Command is in preparation by the PGC Historical Branch.
9. See also "Tentative Program for Master Plan of facilities of Eglin Field," 4 pp., 10 April 1944; map showing "Master Plan, Eglin Field," July 1944; and various photographs of the field and its facilities; all in PGC, "Historical Outline ..." (previously cited), appendix A (Exhibit 63), appendix D (figure 13), and appendix C passim.
10. See "The Development of Tactics in the AAF" (AAF Historical Studies No. 13, July 1944, 107 pp.); and histories of the AAF Board and the Tactical Center, in preparation.
Tactics (November 1943), reorganized in October 1943 as the Tactical Center, were all concerned primarily with developing tactical doctrines for the employment of aircraft and air weapons, but the operational testing of specific equipment was inevitable if operational doctrines were to be formulated effectively. While "material tests" at Orlando were not specifically authorized by any formal directive until June 1944, a large number of their projects was concerned with performance tests of equipment, chiefly equipment procured by Army supply services other than the AAF, such as the Signal Corps, the Quartermaster Corps, and the Corps of Engineers. A notable early example of this activity was the work of the Air Defense Board and the Fighter Command School at Orlando in July and August 1942, in testing experimental models of a light-weight aircraft warning and fighter control system intended for use in the North African landings that were to occur the following November.

The testing activities at Orlando, together with the operational suitability tests at Eglin Field, were all controlled by the AAF Board in terms of jurisdiction between testing fields and priorities among projects; and the AAF Board was in turn subject to the staff supervision of AG/AS OCGA in Washington. Duplication and overlapping between Eglin Field and Orlando were thus made more preventible; a further step in this direction was to place both of them under a newly designated "AAF Center" on 1 June 1945. The relation of these two testing establishments to the Flight Test Section and other test activities of the Material Command was not as clear, however. To remedy this, one of the elements of the plan for an Initial Fighter Air Force, under consideration in April 1944, proposed that Wright Field's flight testing be merged into the Proving Ground Command. NAAD doubted that such a shift "will ... contribute to rapid and effective test" and proposed instead that the Flight Test Section be established as a separate command coordinate with the Proving Ground Command; that both be assigned subordinate commands under Material Command; and that the flight test organization, whose facilities were admittedly "inadequate," be "strengthened" and perhaps moved to a "new base specifically for flight testing." In the proposed AAF reorganization in October 1944, no disposition of the problem was made.

12. AAF Reg. 20-14, 5 June 1944.
13. AAF Reg. 20-14, 21 June 1944.
15. AAF Reg. 20-20, 28 April 1944.
16. Memorandum for Chief, NA, by Col. R.C. Wilson, both in NAAD, 15 April 1944, in NA Reg 18,100 Miss.-Gen.
The AAF and Cooperative Research, 1940-1944

The AAF and MCA experimental facilities described above, together with their industrial and university contractors, necessarily constituted the largest element in the wartime establishment for aeronautical research and development. At the same time, however, there were other military and civilian agencies whose experimental facilities and contracts were vital to the development of air materiel, chiefly in the non-aeronautical types of equipment. Most prominent among these agencies, each with its industrial and university contractors, were the National Defense Research Committee (NDRC, after June 1941 an agency of the Office of Scientific Research and Development); the Navy's Bureau of Aeronautics and Bureau of Ordnance; the National Bureau of Standards and the Civil Aeronautics Administration; and the following Army supply services (after 1942, branches of the Army Service Forces):

- Ordnance Department: bombs, rockets, guns, and ammunition, as well as ground-force ordnance;
- Chemical Warfare Service: special ordnance such as incendiary bombs; as well as ground-force items;
- Signal Corps: radar and radar equipment, both air-force and ground-force items, until the transfer of air-related development to the AAF in Oct. 1944;
- Corps of Engineers: airfield construction equipment, crash trucks, etc.; as well as ground-force items;
- Quartermaster Corps: air rations, flying clothing, and other special personal equipment; as well as ground-force items and items common to the entire Army.

The wartime research importance of these agencies can be roughly estimated by reference to the total research expenditures of each of them between 1939 and 1944, tabulated below, compared to the expenditures of the AAF and the MCA over the same period:

<table>
<thead>
<tr>
<th>Agency</th>
<th>Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAF</td>
<td>$418,755,020</td>
</tr>
<tr>
<td>MCA</td>
<td>55,006,723</td>
</tr>
<tr>
<td>OSRD (including NDRC)</td>
<td>347,955,530</td>
</tr>
<tr>
<td>Signal Corps</td>
<td>160,803,375</td>
</tr>
<tr>
<td>Ordnance Department (Army)</td>
<td>172,775,926</td>
</tr>
<tr>
<td>Chemical Warfare Service</td>
<td>20,501,720</td>
</tr>
<tr>
<td>Corps of Engineers</td>
<td>34,612,072</td>
</tr>
<tr>
<td>Quartermaster Corps</td>
<td>2,946,996</td>
</tr>
<tr>
<td>Navy Bureau of Aeronautics</td>
<td>171,355,325</td>
</tr>
<tr>
<td>Navy Bureau of Ordnance</td>
<td>109,067,894</td>
</tr>
<tr>
<td>National Bureau of Standards</td>
<td>51,117,000</td>
</tr>
<tr>
<td>Civil Aeronautics Administration</td>
<td>3,247,658</td>
</tr>
</tbody>
</table>
The research expenditures of most of these agencies covered more than air material projects. In almost each case these figures also embraced ground force equipment, naval matériel, and equipment common to all the armed forces. Still other Federal research agencies contributed to the solution of AAF problems, such as the Forest Products Laboratory of the Department of Agriculture. In the conversion of the Federal Scientific establishment to war, there were very few agencies that did not directly or indirectly affect the AAF. By 1944 the entire Federal Government was spending about $500,000,000 annually for wartime research in the physical sciences, compared to only 250 millions spent in 1939 by both Federal and private agencies, and that for both war and peacetime research. While this expansion does not necessarily demonstrate that the utilization of the Nation's scientific resources was complete or "total", it nevertheless gives some indication of the conversion of the scientific resources from peacetime pursuits to the development of weapons and war equipment.

In addition to the laboratories, testing stations, or proving grounds maintained by each of these Federal agencies were the industrial and university laboratories that were conducting war research for them. The relative importance of industrial and university research in each agency's program, compared to agency's own research activities, is roughly shown in the following tabulation of expenditures by each agency:

### Total Expenditures for Wartime Research and Development, 1939-1944

<table>
<thead>
<tr>
<th>Agency</th>
<th>Total research expenditures</th>
<th>Expenditures within establishment</th>
<th>Expenditures on industry contracts</th>
<th>Expenditures on university contracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Army Air Forces</td>
<td>$418,755,020</td>
<td>$58,759,308</td>
<td>$557,448,692</td>
<td>$2,452,659</td>
</tr>
<tr>
<td>NASA</td>
<td>95,005,703</td>
<td>91,797,745</td>
<td>74,692</td>
<td>968,174</td>
</tr>
<tr>
<td>OSRD, including NDRC</td>
<td>347,856,830</td>
<td>45,285,132</td>
<td>110,046,850</td>
<td>57,998,336</td>
</tr>
<tr>
<td>Signal Corps</td>
<td>169,686,878</td>
<td>72,739,268</td>
<td>579,998,336</td>
<td>321,455</td>
</tr>
<tr>
<td>Ordnance Department</td>
<td>172,775,914</td>
<td>45,285,132</td>
<td>110,046,850</td>
<td>57,998,336</td>
</tr>
<tr>
<td>Chemical Warfare Surv.</td>
<td>20,391,720</td>
<td>16,544,741</td>
<td>2,634,820</td>
<td></td>
</tr>
<tr>
<td>Corps of Engineer</td>
<td>94,612,072</td>
<td>8,391,821</td>
<td>9,079,308</td>
<td></td>
</tr>
<tr>
<td>Quartermaster Corps</td>
<td>2,945,586</td>
<td>2,491,513</td>
<td>184,680</td>
<td></td>
</tr>
<tr>
<td>Bureau of Aeronautics</td>
<td>171,535,326</td>
<td>6,329,000</td>
<td>160,534,820</td>
<td>197,000</td>
</tr>
<tr>
<td>(Navy)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bureau of Ordnance (Navy)</td>
<td>109,067,894</td>
<td>-</td>
<td>34,569,779</td>
<td>697,171</td>
</tr>
<tr>
<td>National Bureau of Standards</td>
<td>51,117,000</td>
<td>25,452,800</td>
<td>-</td>
<td>29,500</td>
</tr>
<tr>
<td>Civil Aeronautics</td>
<td>3,247,628</td>
<td>836,148</td>
<td>489,148</td>
<td>205,800</td>
</tr>
</tbody>
</table>

In the vast government-industry-university cooperative enterprise suggested in the above statistics, the one new element in World War II experimental activities was the work sponsored by the National Defense Research Committee; all the other agencies were peacetime establishments expanded to a war basis. The NDRC was established in June 1940 with White House approval as an emergency agency to "correlate and support scientific research on the mechanisms and devices of warfare" and to "aid and supplement the experimental and research activities of the War and Navy Departments." 

The wording of this directive thus acknowledged the network of existing Army and Navy facilities both to conduct independent research and to guide, review, and test the research done for them by industry and other non-military scientists, but at the same time implied that the utilization of industrial and university research facilities was far from complete. The origins of the NDRC can probably be traced to civilian scientists outside the Army (chiefly Bush, Compton, and Conant) rather than to any of the military agencies. In fact, the Air Corps, and probably other supply services of the Army as well, two months earlier had opposed a plan for a similar organization, the Air Corps arguing that the existing coordinating bodies were "adequate" and that it preferred "direct" collaboration with industry and the universities. One factor in this skeptical attitude was the traditional direct relationship between the aircraft industry and military aeronautics, a more intimate civil-military relationship than that existing between industry and either the ground or naval arms. The Air Corps, together with the NACA, by 1940 had already gone farther toward scientific mobilization than any other arm. This special air situation was recognized in the NDRC directive (quoted above), which specifically excluded the NACA and its "problems of flight" (aerodynamics, structures, and propulsion) from the work of the new committee.

1. (cont) pp. 306, 314, 323, 309, 310, 304, 308, 303, 302. In addition to the last three columns, which represent expenditures for actual research, are the expenditures for administrative overhead within each agency (sometimes segregated), and funds transferred to other Federal agencies or to State and local governments. For detailed breakdown by all these types of expenditures and by fiscal year, see Ibid., pp. 262-263.

2. Except as otherwise noted later, the source for statements on the NDRC is Ibid., pp. 216-226.


4. 1st Ind. (AG 381 "National Defense" (3-11-40), 14 March 1940), C/AC to AG, 11 April 1940, in AAF 400.112 Test, Development Work.
Once the NDRC was established, Air Corps headquarters saw in the new agency an opportunity to pursue scientific research on a number of non-aeronautical problems whose solutions were vital to the fullest effectiveness of air operations. Coincidentally, in June 1940 the Air Corps’ own experimental program was suffering from the frantic demands for quantity production (described earlier). General Arnold assured the Chief of Staff that the research and development program would be deferred, and suggested that some phases of it might be transferred to "some other governmental agency," presumably referring to the new NDRC. Shortly thereafter a number of scientific problems were submitted to the NDRC by the Air Corps: 5 of them in July and 20 in August, including the historically baffling question of booming-through-overcast. Major W. W. Chidlaw, the newly appointed NDRC liaison officer in the Air Corps, in submitting these problems, recognized that some of them were "abstract," but acknowledged that the NDRC might be able to "disclose immediately likely lines or phases of investigations overlooked by the Experimental Engineering Section, Material Division." He further invited the NDRC scientists to visit Wright Field laboratories "at any time" and promised them the Material Division's "wholehearted cooperation."

Wright Field officers in 1940 were skeptical, and it was some months before NDRC projects were accepted as a normal phase of the Air Corps experimental program. Maj. F. C. Carroll and Capt. E. Z. Bogert suspected that NDRC projects would cause "considerable duplication of the work already under way with the National Advisory Committee for Aeronautics, the National Bureau of Standards, and the National Academy of Sciences"; doubted that the NDRC "can do any more than is already being done by existing coordinating bodies"; and predicted that "most of the work will finally wind up at Wright Field and that...will be taking a great deal of Wright Field's time to bring a number of people up-to-date on what we have already done." When NDRC officials "intimated" to Air Corps headquarters in November that Wright Field was withholding "complete information" in some cases, the Material Division in Washington reminded the Field that the NDRC had the personal support of the President and the Chief of Staff and had "access to certain [funds] which are apparently not governed by the conventional time-consuming rules and regulations which generally are necessary in...Army contracts." Furthermore, one NDRC activity, the microwave radar work at the Massachusetts Institute of Technology, was already showing results, Chidlaw observed, "moving along in high gear and..."
obtaining results and equipment far beyond that which might normally have been expected had the Air Corps and Signal Corps been forced to handle this through regular development channels. Skepticism ultimately disappeared within the Air Corps. Instead of complaints that NDRD scientists were taking the time of Wright Field officers, Air Corps complaints arose in the other direction, that NDRD officials did not visit Wright Field enough, that they were inclined to remain in Washington and "coordinate" at long distance. The dependence of the AAF on the NDRD for certain of its non-aeronautical research became so great that in September 1944 the AAF protested at the "premature" NDRD plans for demobilizing some of its projects at the end of the expected early collapse of Germany. The AAF, unlike the NDRD, planned "no sharp reduction of its research and development program ... until the defeat of Japan," and by the end of 1944 prepared to take over the more "promising" projects that the NDRD had sponsored. 10

The NDRD was a new agency in World War II, but not all of its procedures were new. In fact some of them were not different from the Army's; the NDRD negotiated contracts with universities and industrial firms, much like the Army did; they monitored the progress of the research, and kept higher echelons informed, just as the Army supply branches and material centers did; and the subject matter of the research was both pure and applied science, all directed toward wartime applications of scientific ideas. Unlike the Army, however, the NDRD had no laboratories of its own for conducting independent research or for testing the results of its contractors; and NDRD's contractors were financed under "no profit no loss" contracts rather than under fixed-fee or percentage-fee provisions. Also unlike the Army, the NDRD and its subdivisions were composed almost entirely of civilian scientists temporarily recruited from private positions (437 of them were not salaried, as of spring 1944), whereas the Army's experimental establishments (for example Wright Field) were composed of permanent personnel, both military and civilian, as well as some reserve officers temporarily in the Army, many of them distinguished in fields of aeronautical engineering and most of them comparing favorably with the equivalent technical personnel in industrial and academic institutions. The chief contribution of the NDRD to the development of air weapons was to give an extra impetus to the AAF and the other Army branches working on air weapons; the impetus of additional White House funds in 1940 and 1941, and the impetus of additional scientists, chiefly in universities, many of whom were not

11. NAS Material Division, diary, 2 Aug., 12, 21 Sept. 1944; NAS daily activity report, 9 Sept. 1944; all in APIHI.
accustomed to dealing with the Army until they were mobilized by NDRC officials who "spoke the same language." Once the specific scientific projects were established by the NDRC and properly allocated among the available universities and firms, the AAF and other Army branches concerned assigned liaison officers or project officers to follow the projects, and they received regular progress reports on each project. Most of these projects, totalling 978 for the period from June 1940 to March 1944, represented problems submitted by the Army and Navy rather than problems begun independently by the NDRC. Of these projects, about 125 were sponsored by the AAF, and 500 by the other supply services of the Army Service Forces, the latter including of course many of primary interest to the AAF. By December 1944 the Army's active projects with the NDRC totalled 299, including 70 for the AAF and 229 for the ASF, the latter including $2 sponsored by the Signal Corps for the AAF before the Signal Corps airmac functions were transferred (in Oct. 1944) to the AAFs. 

Among the other research agencies was the Navy Bureau of Aeronautics, which had its experimental establishments at Philadelphia and Patuxent, Md., providing still another source of research and development for the AAF. Unlike the ASF and the NDRC, the Navy's relationship toward the AAF was, of course, competitive. Both of their material centers were developing many items of aircraft, engines, armament, bombin equipment, and other apparatus that were similar if not identical as to their tactical requirements and uses. Aside from the Navy's special equipment for carrier-based aircraft, most of its equipment was, after all, common to military and naval aeronautics. Obviously there was duplication of effort between them, in spite of the occasional assertions to the contrary by either or both of the arms. The responsible AAF officers usually denied, not that there was duplication, but that there was "unnecessary" duplication of effort, and the two research and development programs were frequently rationalized as a desirable situation of "parallel development" not unlike the independent research conducted by two or more scientists on the same idea, or the independent design of a bomber by two firms (for example, the Boeing B-17 and the Consolidated B-24). The "begsy of duplication" in scientific matters, the allegation that the "duplication of equipment and effort is in itself evil and wasteful," was attacked by Col. Carl F. Greene, the AAF liaison officer at the NACA, as follows: "Almmost all scientific findings, concepts, and opinions ... are controversial"; two or more laboratories "may well contribute to the wholesome and necessary process ... of checking and questioning the teachings of the original investigators"; and the "right of research agencies to scrutinize and disagree with each other's work is as valuable in achieving scientific progress as is freedom of speech in forming public opinion." 

12. RAE, MD to NAS, 5 Dec. 1944, in AAF 334 Records, Miss.  
13. RAE, Supply Division to Col. Carl Spatz, 29 July 1945, in AAF 400.112 Tests and Experiments (U).  
Whether this theory was also a fact, as between the Army and the
Navy, cannot be definitely evaluated here, without specific analysis of
the history of various material projects, successful and unsuccessful,
involved. One estimate by the Bureau of Aeronautics, in February 1942,
could cite only three material developments that had resulted from
such divided air forces: the aircraft-launched torpédos (Navy), the
dive bomber (Navy), and the heavy and medium bombers (Army) were cited
as examples of "progress that might not have been realized from a
single air force."16

Whatever the merit of these claims (and each of the specific ex-
amples might be debated), the two experimental establishments did not
actually work entirely independently of each other. Joint consult-
tation between them was common, including periodic reviews of their re-
search and development programs, in 1939 as in 1944; joint conferences,
in NACA committee deliberations, a standard procedure that dated back
to the very beginnings of the NACA in 1915; and the system of liaison
officers exchanged by the two material centers, a practice that began
apparently in 1939.17 The Navy was probably more aggressive than the
AAF in pursuing this liaison. Thus, the AAF had only a single full-
time officer with the Bureau of Aeronautics (Col. John H. Sams) and
while his reports on Navy developments were frequent and informative,17
MMD and Wright Field were "frequently ... criticized for lack of liaison,"18
especially at Navy tests at locations other than Philadelphia and Patuxent.18

15. Memorandum for C/AAF by Rear Admiral J. H. Towers, BuAer, 14 Feb. 1942,
in AAF 452.1 Production of Aircraft.
16. See OCAC O.M. 10-4, 14 June 1939, in AAF 300.6 OCAC Memo, Numbered (U).
17. MMAD Material Division, diary, 2 June 1944, in APIHL.
18. Some of Sams' reports are in AAF 380 Programs and Projects (20
May, 20 June, 24 Nov. 1944), 360.2 Development and Research
(12 Oct. 1944), and 000.71 Interviews (30 Sept. 1944).
The Navy, on the other hand, carefully attended most AAF mock-up inspections and tests; stationed over a dozen permanent officers at practically all of the laboratories and units at Wright Field, pro-
voking one consent that every AAF project officer had a Navy officer "breathing down his neck"; and in August 1944 took steps to copy the plans and drawings of many of Wright Field's test facilities for use in expanding its own naval air material center.

The AAF was opposed to formalizing this collaboration with the Navy to the extent of throwing its research and development program together with the Navy's into a committee that might tend to remove the AAF from direct control over its own material activities. Thus in 1940 the Navy suggested that very procedure--a proposed joint sub-committee of the NACA--and was scolded by the Air Corps for abdicating, in effect, its basic responsibility for military requirements and tactical evaluations; the Army and Navy "should not admit that the pressure of business makes it necessary to transfer to a third agency ... the job of coordination between us"; the existing Army-Navy liaison system "can keep the two programs integrated without outside non-military help"; it is the tactical requirements, known only to the Army and the Navy, rather than technical limitations or scientific frontiers (the province of the NACA) that must determine the projects and priorities of the research and development programs; and, finally, the Navy proposal "would place in the hands of the NACA a control over naval and military experimentation never intended by the acts establishing and empowering the NACA with aviation experimental authority ... not ... to the best interests of our two services ..."

Now was any other permanent or ad hoc wartime committee appointed to control the Army and Navy air programs for research and development. The Joint Chiefs of Staff, established late in 1941, did not assume jurisdiction. However, they did set up a Committee on New Weapons and Equipment in 1945, but it was more a device to bring the civilian head of the NRC (Dr. Vannevar Bush) into the strategic councils of the high command than a means of reducing the prerogative of the AAF. Furthermore, the committee's functions were largely advisory and its activities have apparently not seriously affected the direction or emphasis of the AAF program.

19. Memorandum for Chief, Engineering Division, by Bucker General Representative at WF, 23 Aug. 1944, in ATSC 045.2 Navy (U).
Within the War Department, the AAF's growing autonomy after 1939 had repercussions on its research and development program. The General Staff, which had earlier in the past two decades adversely affected (for example) the development of the heavy bomber, had no appreciable influence on the development program after 1939. G-4 had no representation on the Kilner Board in 1939, and only a junior officer on the Emmons Board in 1940. In August 1941 G-4 was given staff control over all "defense projects" throughout the War Department, including development, procurement, and supply of matériel, and in September a directive reminded the supply services that the Chief of Staff and his deputy were responsible for "the coordination of the functioning of research and development agencies" throughout the War Department. However, the correspondence and other records of G-4 reveal little concern or interference with the AAF program by higher authority after 1940. Soon General Arnold, Chief of the Air Corps, became Deputy Chief of Staff for Air, a move that was symptomatic of this growing autonomy. Thus, in February 1941, when the Secretary of the General Staff sought to review the Air Corps research and development program by asking for comprehensive data on Wright Field projects, Arnold halted the review with the query, "Since when did the air corps cease to be a part of the War Department?" and Maj. Gen. C. H. Brett, the new G/3, entered the Material Division to "file away and forget" the General Staff request. The budget section of the General Staff likewise tended to lose its policy-making functions with respect to the AAF; in July 1941 the Material Division was able to prepare its research and development budget independently of the long drawn-out rigmarole of coordination with the General Staff. After 1941, the budgets as prepared by the AAF tended to survive substantially as they were presented to the General Staff. By 1943 General Staff activities affecting research and development began to be revived, with the establishment of a New Developments Division in August 1943, essentially the reappearance of the research and development section of G-4. Its directive was worded in very comprehensive and all-inclusive terms: "the innovation, development, and application of new weapons, devices, and techniques of military value," subdivided into eight large functions apparently covering every phase of planning, supervision, and control.

22. See G-4, case files, and index to them, 1921-43, in AAF War Department Records Branch.
23. AG 400.112 (1-13-41), 5 Feb. 1941; memorandum for Col. Orlando Ward, Secretary of NQS, by Arnold, 11 Feb. 1941; and notation by Brett to Brig. Gen. C.F. Scholls, 19 Feb. 1941; all in NQS Development Engineering Branch file on "1941 FY R&D Program."
24. Inter-dek Memorandum, Lt. Col. B. W. Chadlaw to Brig. Gen. C.F. Scholls,
In actual practice, however, its chief function seems to have been to gather information on the possibilities of unconventional weapons not yet accepted tactically by either the ground or air arms, such as long-range guided missiles (both air-launched and ground-launched), and to arbitrate competition between those tactical and procurement arms seeking to obtain a portion of the responsibility for developing and applying such weapons.

Beyond the General Staff and the Navy and their changing relationships to the AAF research and development programs, there occasionally were attempts, during the course of the war, to establish a "Scientific High Command" intended to expedite the "cooperative" development of new weapons for air, ground, and naval operations. Such proposals for Federal-wide coordinating bodies were not peculiar to the war (some of the pre-war proposals have been discussed earlier), but during wartime they were more frequent.

Within the War Production Board, for example, there arose in June 1942 a proposal for a WPD Office of Technological Development, to "utilize the scientific resources of the country ... and to investigate new processes, devices, and ideas," all "in coordination with" other government agencies. No AAF representatives were present at the hearings on the proposal, but objections were registered through the WP Aircraft Branch which echoed, in effect, the opposition of the AAF. W. J. Augustine of that Branch opposed the move as (1) sheer duplication of the work of existing agencies, including Wright Field, the NACA and the NDRC, and (2) "an interference rather than a help in speeding the use of new developments in the aircraft industry." At the same time a National Resources Planning Board witness (Dr. Robert Leigh) agreed that aeronautics needed no more "cooperation," since aeronautics was one of two or three fields of science "where cooperation and research between government and private industry is very well developed." An expansion of this proposal came to the attention of Material Command headquarters in September 1942, when a WPD employee—a "Senior Program Procedure Analyst (whatever that is)"

came wandering into my [Col. B. W. Childs] office one afternoon and started to ask a lot of rather vague and disconnected questions as to how we handled development problems, how we maintained liaison with outside research agencies, how we did this and that, etc; ... it was quite apparent from the vague type of question asked that he was not very sure of his ground and since his very ambiguity made me damned reluctant to put out too much, I started doing most of the question asking myself."

24. (cont) 8 July 1941, in M&G Development Engineering Branch file "1942 FY R&D Program."
26. Memorandum for Director, WDD, by B/W, 15 Oct. 1943 (copy), in M&G Development Engineering Branch file "$0,105 WDD"; and WD-F General Council
The WPB employee left a draft of the proposed directive with Chidlaw, and when General Keohs saw it the next day he "hit the ceiling" and wrote a memorandum to the Under Secretary, castigating the proposal on several points: there is already "too much coordination"; "the surest way to throttle [aeronautical development] is to set up another bureau in Washington to stick it with committees, programs, meetings, priorities, and directives"; and the WPB's new prerogative would permit the WPB to "direct" research and development, to "control the time [The moment of standardization] when improvements in military equipment will be introduced into the production line," and to prevent the services from initiating any research project "without a certificate of necessity from the WPB." 26

The War Production Board proposal, which was not widely publicized, was shortly withdrawn by Donald Nelson, WPB chairman, due to the intervention of the Under Secretary, but meanwhile a similar proposal was placed before the Senate by Senator Harley M. Kilgore. The directive of his proposed Office of Technological Mobilization, embodied in bill S. 702 in August 1942, was similar in language to the WPB proposal. The armed services, including the AAF, generally opposed it, on grounds such as those expressed by Chidlaw the month before. Likewise most of the spokesmen for industrial and university scientists opposed it, but with more emotional and less reasonable phraseology, including warnings of "regimentation," of the destruction of "freedom and the competitive spirit," and of "totalitarian powers that should be entrusted to no human being." 29 In fact, some of their arguments, that the new OTM would impose centralised control over science, contradicted some of the Army arguments, that the OTM would result in divided and conflicting controls. On the other hand, a few advocates did support Senator Kilgore, including a union of scientific workers, Butler Brothers (jobbers who dealt largely with small firms), a minority of scientists, and Henry J. Kaiser and a

27. Transcript of WPB hearing, prepared "for record" by W.J. Augustine, 5 June 1942, and sent to Chidlaw, 20 Oct. 1942; in NASA Development Engineering file "700.430 Kilgore ...":
few other industrial executives. Dr. Vannevar Bush, the director of the Office of Scientific Research and Development (including the NDRG), whose position was of course threatened by the bill, agreed that wartime "centralized control" was necessary but argued that this was already being accomplished through the NDRG's "finely meshed machinery" of Army-Navy-civil scientific relations.

The AAF point of view toward such a scientific high command was expressed as follows, by Col. B. W. Chidlaw, in October 1942: "There is too much so-called "cooperation"; we are about to be killed with kindness and cooperation—we are slowly being helped to death!"

As far as my own job is concerned, I now spend about as much time coordinating and cooperating as I do getting some actual constructive work done. In all honesty, I do not see (unless they build up to a tremendous organisation) how they can expect to keep abreast of the rapidly changing military situation and provide us with this superior equipment they promise, unless they have within the show a military sub-division about as large as the existing research and development set-ups now found in all the services. To us, it would mean just one more coordinating phase, and since it would be the highest phase, would present more trouble than all the rest added together.

As to technical personnel, there were no scientists and specialized personnel available in aeronautics to handle such work:

we have just about everybody that amounted to anything in the technological aeronautical world already corralled within the confines of our own control, that is, within the Material Command, the Bureau of Aeronautics, the MCA, and the aeronautical industries in general. ... unless the Technological Mobilization Corporation took over the above organisations in entirety, a lapse of development continuity is inevitable and one which we simply cannot afford at this time right in the middle of a war.

The Kilgore proposal eventually expired, after being revived in 1943 and 1944 in other forms. AAF control over its own development program was probably never seriously threatened; and aside from the burden on the AAF in marshalling data for the committee, an incidental benefit might have accrued to the AAF. The committee and its proposals and testimony did probably serve as a "gadfly" on the AAF and the other procurement services.

More important than a hierarchy of inter-agency committees was the basic simple cooperative character of aeronautical research and development, previously described, with experimental activities appropriately divided into (1) basic or fundamental research work, handled at the NACA, at educational institutions, and occasionally at other governmental laboratories; (2) experimental development, at Wright Field, at the Bureau of Aeronautics, and at industrial firms; (3) applied development at the manufacturer's plant, with the use of "community facilities" like the NACA wind tunnels; and (4) test and acceptance work, handled ultimately by the "buyer," that is, the AAF or the Navy, with occasional technical advice from the NACA and perhaps the Civil Aeronautics Administration. This historically-consistent structure and practice appeared to be as valid in 1944 as in 1959.
Part C

RESEARCH AND DEVELOPMENT IN ENGLAND, 1714-1939

The progress of aeronautical research in England is closely connected with the advances made by British science in general. Scientific achievements in 18th century England were numerous, but during the 19th the leadership in scientific research tended to pass to France. The appearance of the industrial revolution in England, however, gave rise to a new era of scientific activity. The new industries utilized scientific discoveries in countless unique and hitherto undreamed of ways, and gave to British science that essentially practical quality which it still preserves.

Nevertheless, although great progress undoubtedly was made in scientific investigation, it was haphazard and uncertain. While British industry profited greatly from new discoveries in theory and techniques, there was no clearly established channel between the industrialists and the scientists; nor did any central coordinating organization come into existence before 1900. Among the university professors and their students, there was a belief that scientific investigation should deal with basic fundamentals rather than practical applications of new ideas. To accept a commission to carry out a particular piece of research for a business establishment was considered "bad form" by some.

The rise of modern Germany as a great industrial nation during the last three decades of the 19th century brought about, indirectly, an expansion of British science. As a part of its efforts to meet German, and incidentally American, competition, British industry increased its exports of production goods, technical machinery, and railroad equipment. Scientific research benefited from this, and early in the new century efforts were made with the backing of the government to organize special laboratories and research centers whose findings would be available to all interested groups. The National Physical Laboratory, founded in 1900, was organized for such a purpose.

With the outbreak of the First World War, science, along with agriculture and industry, was pressed into service. Never before had it been used on so large a scale, and by the end of the war, there was a virtual mobilization of scientists in almost every field for the sole purpose of increasing the destructive power of modern weapons, and assisting industry to greater and greater achievements in large-scale production. In 1915, a Department of Scientific and Industrial Research was established by the government to remove the defects in industrial development and organization which the war had brought out into the spotlight; meanwhile, already existing scientific bodies were utilized to the utmost.

This impetus was not completely lost following the peace, but there was, naturally, a slackening up all along the line. The larger industries

1. Prepared by Dr. John F. Ramsey, AEHI, April 1945.
remained more "research conscious" than ever before, but smaller firms had a tendency, probably for financial reasons as well as any other, to stick to old and outmoded methods. On the other hand, the universities maintained a much closer contact with industry than previously. It was no longer considered "bad taste" to assist some manufacturer to develop more efficient techniques and processes. Likewise, the industries themselves sought to open up new channels to the sources of research by scholarships, and by special grants for investigation. The Chemical Industries, Ltd., led the way, and other corporations soon followed. By 1937, the Department of Scientific and Industrial Research had been able to spend £372,127, and maintained eight special research establishments, well provided with staff, thirty-twos and committees, and maintained close contacts with twenty industrial research associations. The present bulk of British scientific research, therefore, comes from three general sources: (1) the universities; (2) government laboratories; and (3) the laboratories of industrial firms. Although not usually responsible for scientific investigation themselves, the numerous scientific and professional societies perform the highly necessary work of coordinating much of the research in universities, and furnishing a link between science as a whole and the general public.

Although the results of scientific investigation have been impressive, the actual sums spent in this field are small, especially when compared with the amounts spent in the United States or the Soviet Union. According to one estimate, 1/10 of 1% of the British national income is spent on scientific research, while approximately 6/10 of 1% is spent in America, and 8/10 of 1% in the Soviet Union. It is essential to bring home this capital deficiency of British science, the fact that its total development in relation to national needs is grossly inadequate.

In 1937, a total of £3,245,000 was spent by the government on scientific research. Some of the larger expenditures were allocated as follows:

<table>
<thead>
<tr>
<th>Department</th>
<th>Expenditure</th>
</tr>
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<tbody>
<tr>
<td>Fighting Services</td>
<td>£1,536,000</td>
</tr>
<tr>
<td>Council for Scientific &amp; Ind. Research</td>
<td>535,000</td>
</tr>
<tr>
<td>Ministry of Agriculture &amp; Fisheries</td>
<td>469,000</td>
</tr>
<tr>
<td>Medical Research Council</td>
<td>195,000</td>
</tr>
</tbody>
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The Department of Scientific and Industrial Research gave £105,549 to the National Physical Laboratory, and spent £35,850 in grants to research associations; the remainder of its budget went to chemical and agricultural projects. The Fighting Services gave £727,500 to the RAF, £416,500 to the Navy, and £318,500 to the Army for research and development.

The advancement of the science of aeronautics was conditioned by the developments so briefly sketched in the preceding pages, as well as by military needs and requirements. Although the first actual airplane flight

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2. "Research - A National Resource", Section II, Industrial Research. (National Resources Planning Board, 1940)
3. Ibid.
4. J. J. Bernal, The Social Function of Science, 63-4
5. Ibid. 65
6. Ibid. 422
7. Ibid. 427

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Inland did not occur until 1901, interest in the possibility of aeronautics had existed for a long time previous, and had expressed itself in aerostation or glider experiments. Then Colonel J. B. Capper became head of the government balloon factory at South Farnborough, he made this factory a center for aeroplane experiments and investigations that paved the way for H. V. Roe's first flight in 1908.

As early as 1906, HovetColonel J. B. Capper of the Royal Engineers had suggested that a committee composed of scientists, engineers and naval representatives might undertake the scientific investigation of aeronautical techniques. However, the government was not at this time greatly interested in the development of heavier-than-air machines, nor was it prepared to make a large expenditure of money for additional investigations. The Committee of Imperial Defense had advised that the airplane experiments be conducted at the balloon factory at Farnborough be dropped, and when, by 1909, two experimental planes had consumed a total of 52,500, the government decided that the results did not warrant such an outlay of funds, and ordered the factory to confine itself to airship development.

No doubt underlying these policies was not so much a complete lack of faith in the airplane, as a desire to await further developments, and a confident belief that whatever happened, Britain could catch up if necessary. R. M. The Secretary, well expressed the national feeling toward aircraft in a speech delivered in 1910.

Then a new invention like the submarine, or the motor comes to light, the Englishman is usually behind. Give him a few years and he has not only taken care of himself in the meantime, but is generally leading. As it was with these inventions, so I suspect it will prove to be with aircraft.

At the same time, already established services regarded this fantastic newcomer with something a little less than enthusiasm, feeling that only the Army and the Royal Navy could properly carry out the defense of the British Isles. Furthermore, there was a perfectly natural desire to protect the national investment in the Royal Navy, and a hesitation to rush into the development of a weapon that might render sea-power obsolete. According to an official report:

... up to the end of 1911, the policy of the Government with regard to all branches of aerial navigation was based on a desire to keep in touch with the movement rather than to hasten its development. It was felt that we stood to gain nothing by forcing a means of warfare which tended to reduce the value of our insular position, and the protection of our sea-power.

It was this attitude which led the British military and naval authorities to refuse the 'right' invention when it was offered to them.

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9. Ibid., I, 157
10. Ibid., I, 75
11. Ibid., I, 3
Nevertheless, Colonel Fullerton's suggestion was not entirely disregarded. It was revived in a somewhat altered form in 1909 when Haldane, the War Secretary, conferred with Lord Rayleigh and Dr. Richard Glasebrook of the National Physical Laboratory to secure the services of that institution in aerial experimentation. After obtaining the approval of Prime Minister Asquith, an Advisory Committee for Aeronautics was created with representatives from the Army, Navy, Meteorological Office, and certain distinguished scientists. At about the same time, the National Physical Laboratory organized a special section of the Engineering Department to deal specifically with aeronautical research, and an elaborate plant and laboratory were set up at Teddington. Even in this relatively ancient period of aviation history, 12

...mathematical and physical investigations were continuously carried on at the laboratory and improvements suggested by these researches were put to practical test at the factory. Questions of air resistance, of the stresses and strains on materials, of the best shape for the wing of an aeroplane, and the best fabric for the envelope of an airship - these and scores of other problems were systematically and patiently attacked.

Meanwhile, after 1910 there was a considerable change in the government's attitude toward heavier-than-aircraft. A good many factors were involved. Experiments with airships had not gone too well, and, by contrast, French airplanes had a long series of outstanding achievements to their credit. As a result of the troubled international situation, Germany, long an industrial rival, began to appear as a political competitor as well. When the success of Count Zeppelin's airships seemed assured, growing British dislike of Germany, according to the official historian of the Royal Air Force, made the airplane more popular in England. 13

In 1912, the balloon establishment at Farnborough became the Royal Aircraft Factory, later to be renamed the Royal Aircraft Establishment. The Factory, working in close cooperation with the Advisory Committee and the National Physical Laboratory, soon became the center for practical experimentation with machines in actual flight, and it is to the research and experiments of these three bodies that Britain owes her Royal Air Force. The Establishment began modestly with about a hundred workers, but by 1916 it was employing 4,600 people, and owned a plant consisting of many buildings. 14 To develop an adequate engine, an engine testing plant and wind tunnel were set up. However, in this case, the engine industry feared the possibility of a government monopoly of engine construction, and refused to send their motors to be tested. Not deterred by this lack of cooperation, the Factory engineers went ahead on the problem, and by 1913 had designed their own engine, blueprints of which were made available to the trade. 15

12. Ibid., I, 160-2
13. Ibid., I, 5
14. Ibid.
15. Ibid., I, 160-2
More successful, perhaps, was the Designing Office which was created to furnish drawings from which manufacturers could construct new models. By 1916 it had a personnel of 275 draftsmen. It was also used during the war to assist the makers of such peacetime items as phonographs, furniture, cars, and the like to convert to wartime aircraft production, and in two years it issued 300,000 drawings to firms hitherto unfamiliar with plane manufacture.

Meanwhile, the Royal Flying Corps came into being in 1912 with its Military and Naval Wings, and to coordinate these two branches, an Air Committee was set up in July of the same year. The Naval Wing was under the control of the Naval Air Department commanded by Captain Murray Suter. Being under the strict control of the Admiralty, it was never entrusted with much power or given much opportunity to develop along independent lines. The Military Wing, however, enjoyed much greater freedom, and was able to carry out much research on its own. In March 1913, an experimental branch of the Military Wing was founded under Major Herbert Musgrove to carry out investigations. During its existence, it dealt with ballooning, meteorology, bombing, musketry and gunnery, and cooperation with artillery.

By this time, two types of investigation were being carried on. At the National Physical Laboratory, research on basic flight problems was conducted, while in the Military Wing and its squadrons the practical application of new theories was worked out and tested with actual planes. The Royal Aircraft Establishment served a similar purpose. Early in 1914, a headquarters flight was placed at the disposal of Major Musgrove to serve as a further link between theory and practice. Especially important were the researches carried out by this headquarters flight in airplane wireless.

The outbreak of the war, therefore, found England with a small but active air force, and the beginnings of an excellent research organization. However, in comparison with the other great powers of Europe, British aeronautical research in these early days was very poorly endowed. Between 1908 and 1913, Germany had spent about $32,000,000 on aeronautics. France $25,000,000, Russia $12,000,000, and England $3,000,000.

The war brought about a great expansion of existing establishments for research without making too many changes in organization. In 1917, the section of the Engineering Department of the National Physical Laboratory which had been handling aeronautical investigations was reorganized as the Department of Aerodynamics and a number of scientists were assigned specific research problems. One of these dealt with the engine question. Although the Royal Aircraft Establishment had designed an engine, this had not been developed by any private firm, and the Royal Flying Corps was virtually without a suitable engine. Pending the development of an adequate power plant of British manufacture, engines were obtained from the French until 1915 when certain British motors began to come off the assembly lines. Unfortunately, these were not too satisfactory, and in spite of the efforts of the RAE and an Internal Combustion Engine sub-committee of the Advisory

Committee on Aeronautics, British aviation during the war was considerably handicapped by the lack of a suitable rotor. 17

In 1920, the Advisory Committee was renamed the Aeronautical Research Committee, and its functions were considerably expanded. Sub-committees were set up for accidents, air inventions, aerodynamics, engines, meteorology, and evaluation. The functions of the committee were defined as follows: (1) to advise the Air Ministry on scientific problems; (2) to make recommendations for, and to initiate research; and (3) to supervise aeronautical research at the National Physical Laboratory. Through its activities, the committee made important contributions in the following fields of aeronautical investigations: (a) scale effect; (b) stability and control of airplane; (c) auto-rotation and climbing; (d) flutter; (e) airfoil theory; (f) motion of the surface layer; (g) resistance, turbulence, and streamline motion; and (h) airflow at sonic speeds. 18

The committee also lent in close touch with the other aeroplane interests in aeronautical research. Through the Air Ministry and the Director of Scientific and Industrial Research, it was able to coordinate its work with the studies being undertaken at the various Air Ministry experimental establishments. Through its contacts with the Society of British Aircraft Constructors, it was acquainted with the needs of civil aviation, and was frequently used by the Air Ministry to distribute grants-in-aid to individual researchers. 19

Between 1920 and 1939, the National Physical Laboratory's work on aeronautics was on various problems. Although biplane stability problems were fairly well understood by 1915, the same cannot be said for the monoplane. When the shift to this type of plane occurred, the National Physical Laboratory made a special point of studying monoplane stability, and was engaged in this research at the outbreak of the war in 1939. During this period, the NPL worked in close contact with the distinguished physicist, Professor J. L. Taylor of Cambridge. Close attention was also paid to the research of Professor Brandt and von Kármán in Germany. 20

When the Air Ministry and Royal Laboratories was established in 1918, little change was made in the research set-up. However, in the 1920's changes were made in the type of coordinating and inter-relating the functions of the different agencies. After the war, research had been assigned to a directorate of the Air Council known as the Technical Department. However, the Royal Aeronautical Society felt that the arrangement was not favorable to the study of basic flight problems, and at their urging, the Air Council of the Ministry set up a new directorate of research and placed it under the Department of Supply and Research. 21

However, in time this arrangement was criticized on the grounds that the head of this department was too much involved with supply to devote himself adequately to research. In 1935 the duties of the Supply and Research Section of the Air Council were split in two: there was now to be one member for research and development, and one member for supply and organization. Under research and development were placed the Directors of Technical Development, Scientific Research, and Aeronautical Inspection. Special mention should be made of the Director of Scientific Research as he exercised a supervisory control over the Air Ministry's Experimental Establishment. There were also the before-mentioned labs at Watlington for low aircraft, and at Fellers for seaplanes, and the Air Ministry laboratory at Westhampnett for chemical and chemical research. Thus, research functions were taken out of supply and given to a member of the Air Council who was to be able to devote full time to them.

Civil aviation research, with potential value for military aviation as well, was subsidized by governmental subsidies or special grants. For the year ending 31 March 1933, the government made the following grants to assist civil aviation:

- Imperial Airways, Ltd. . . . . . £ 351,000
- Light airplane clubs. . . . . . 8,500
- National Flying Services, Ltd . . . . 1,500 (23)

For a nominal fee, the National Physical Laboratory was available for special research for any of the private aeronautical concerns. As previously indicated, in 1927, the government made £1,536,000 available to the fighting services for aeronautical research.

While government subsidies to the air industry have usually been welcomed, there has been some opposition to the amounts spent on research—small as they were. G. R. Gray, an ardent admirer of Nazi Germany and editor of the influential magazine, The Aeroplane, violently attacked all of the efforts of British cabinets to concentrate and coordinate aeronautical research in the 1920's and 1930's. Much of his ire was reserved for the Farnborough Establishment and the £400,000 a year which the government expended upon it. Typical of the editorials which appeared in The Aeroplane is this excerpt from the editorial page of the issue of 12 February 1936. Quoting Charles V. Allen of the Society of British Aircraft Constructors, Gray stated that:

"The problem of aircraft is not solved by logical deductions from exact data... Aircraft design is an art and not a science, and the point is soon reached where the resources of science break down and the creative genius of the designer in the exercise of his art becomes paramount." In other words, (concludes Mr. Gray), our £400,000 a year for Farnborough goes down the drain to finance a lot of myopic pseudo-scientists poring over haystacks on the off chance that there may be a needle in one of them. (25)

22. Ibid.
24. See above, p. 123.
25. The Aeroplane, 12 February 1936, p. 193
The unprecedented demands made upon British production after the outbreak of the Second World War finally brought about a complete reorganization of research agencies. In May 1940 a Ministry of Aircraft Production was formed. According to the enabling act, one of its duties was "the design and inspection of, and research and experimental work in relation to any articles required by the Secretary of State for Air, or the Air Council for the purpose aforesaid." Aeronautical research, therefore, was now a part of this new ministry, and no longer a responsibility of the Air Ministry.

In the Ministry of Aircraft Production, research was placed under a Controller of Research and Development, and a Controller of Communication Equipment. The controller of Research was responsible for scientific investigation connected with all airborne equipment, (excluding items like radar and radio which were the responsibility of the Director of Communication Equipment), used by the RAF, Navy, and civil aircraft being manufactured under the Ministry of Aircraft Production. To ensure the proper distribution of research projects, as well as the conservation of effort for major projects, there was a Directors Research and Development Committee meeting twice monthly. It consisted of the principal directorates in the Department of research and development, and was advised by Technical Advisory Panels composed of the senior representatives of the nine experimental establishments and the headquarters directorates concerned.

The Department of R & D was divided into directorates as follows:
(1) Scientific Research, (2) Technical Development, (3) Engine Development, (4) Armament Development, and (5) Communication Development. The responsibilities of the Director of Scientific Research were especially great. He was to see that the necessary scientific work was done, and applied in immediate development, and therefore he had a certain supervisory control over the Establishments and certain departments at the Ministry. He was also responsible for the assignment of a pool of scientists maintained by the Ministry of Aircraft Production to the various directorates where they could work as needed. Through the Scientific Advisory Council of the Ministry of Supply, he maintained contact with research staffs of other government agencies. Likewise, he coordinated and directed to the proper place the work of the various Operations Research Sections at the R & D scene.

The Director of Technical Development was responsible for the airframe of British planes and most of the equipment, as well as the investigation and testing of all new and experimental designs. The work of the Director of Engine Development not only included the power plant of British planes, but also covered propellers, fuels, and oils. The work of the other directorates is clearly indicated by their names, and does not require further description. The personnel of the scientific and technical staffs at the Ministry of Aircraft Production totaled about 5,800 persons, of which approximately 34 per cent were civilian.

28. Ibid.
29. Ibid.
30. Ibid.
Naturally, the work of the Royal Aircraft Establishment was entirely concentrated on war problems. The work was usually of a long-term nature involving projects taking more than 12 months. It was estimated that at least 50% of the tests and studies had an immediate practical application. Investigations covered such fields as aerodynamics, engines, radio, instruments, photography, aircraft structures, armament, electrical engineering, physiology, and flight tests.

It was suggested by some that the Ministry of Aircraft Production should continue as a separate ministry after the war, and be responsible for all "research, development, and supply of aircraft not only for the Royal Air Force, but also for the Army, the Fleet Air Arm of the Royal Navy, and civil aviation." However, there is likely to be much opposition to this plan from the older services, and at present it is impossible to say just what sort of research organizations will be maintained in England after the war.

In conclusion, it may be said that aeronautical research in England has suffered from some of the general problems of British scientific investigation. There seems to have been some unwillingness on the part of corporations to recognize the value of industrial laboratories, and, as pointed out earlier, science in England is poorly supplied with money especially when compared to the generous outlays which are provided by the American and Soviet governments. There has also been a tendency, observable in some quarters of British science, to favor so-called practical application and technological development at the expense of basic research; on the other hand, those engaged in research at the universities have, in the past, felt a certain obligation to remain in this work and not become too much involved in practical applications of basic ideas. However, there is little doubt that these attitudes were considerably modified by the last war, and have probably been completely broken down by this present one.

On the other hand, aeronautical research has enjoyed certain definite advantages in the United Kingdom. One the need for this type of investigation was recognized, the organization of the research was logical and well-conceived, and if the appropriations have not been too large, the quality of most of the work was high, and compares favorably with work done in other countries. The combination of a research organization like the National Physical Laboratory with a testing establishment like the Royal Aircraft Establishment appears to have been admirable. Since the RAE possesses ample facilities to construct and test full-scale models, the ideas and theories of the NPL could readily be translated into prototypes. In the opinion of Air Vice-Marshal Sir Sefton Brancker, "practically all private designers, although some of them may have been bitterly opposed to the policy followed in connection with the Royal Aircraft Factory, admit that they owe much to the high standards set, and to the information distributed by this government institution." 33

31. Ibid.
32. Ibid.
33. Jones, The War in the Air, III, 259
Also praiseworthy is the close connection maintained by the Air Ministry with the National Physical Laboratory, and the Aeronautical Research Committee. Under this set-up, it is a comparatively simple matter to study the problems of aeronautical research, institute the appropriate scientific investigation, and then, through the medium of the R.L.I., apply the new discoveries in practical experiments and test flights with full size working models. This close union of theory and practice is one of the most satisfactory procedures in British aeronautical research today, and will doubtless be maintained in the coming years.
Part D

LISBON, PORTUGAL, JANUARY, 1918-1919

There are several types of the current war, none of which are unique. In this situation, the Allies are driven by the necessity of "war". They are not fighting with their hands what we lack in physical resources. Germany did not fight against her resources, but against what she lacked in resources. In the nineteenth century her universities proceeded to foster research in scientific fields, while elsewhere a certain academic and commercial force science from "contaminating" the university until a late date. Her scientists, engineers, and industrialists had initiated the establishment of research schools, research institutes, and the publication of specialized scientific journals long before these were common elsewhere. Perhaps the greatest advantage of German science was its association with the tradition of German learning, plus the most creative scientist to the scientist by virtue of official recognition for his achievements. He was an important and highly respected member of the national and local community. In France, England, and in the United States, he has to fight for this recognition; in fact it is doubtful whether in the United States he ever has achieved the public esteem long ago granted him in Germany.

The science and precision of the German researchers became proverbial. He had an intense curiosity together with a belief in the absolute value of pure scientific truth. With this mental approach and equipment, with a high degree of state and community emphasis on the advantages of German science came in the last quarter of the nineteenth century after the industrial revolution had arrived in force. German industrialists proceeded to accept the theoretical scientist, which is more than could be said for their contemporaries in England and the United States, whereas the "practical" business man in the latter two

countries tended either to despise, or at least to ignore, the more theoretical
scientists. In Germany the industrialists tended to ally themselves with
and to make use of the theoreticians. In the chemical industry this close
linkage between industry and the new theoretical chemists paid handsome
dividends.

But more than industry benefited from the efforts of the theoretical
men of science. The state was involved, and it was in Germany that the full
value of science in war preparation was first appreciated. To be sure, the
military did not entirely share the enthusiasm of industry for science;
neither did it in England or the United States. But there was not enough
opposition within military circles to prevent the German Army from being
the only one which possessed any effective scientific support when it went
to war in 1914. Germany's scientists were more numerous than those of
the other belligerents, and (more important) they already were in close contact
with industry. To overcome this combination required the combined effort
of the entire world, and even then the issue was in doubt for a time.

After World War I, German science reached its apex. The state now had
supported science with an effectively organized system of elementary
and advanced science. Now it supported organized research. True, the sums
were not large by our standards, but within the limits of her ability, Ger-
many led the way in organized research. It is estimated that in 1930, 10
million Reichmarks were spent upon research by the Reich government, while
the state governments contributed approximately 20 millions more, all exclu-
sive of military research. And this was more than Britain was spending,
when the estimated amounts being spent in industrial research were added to
these figures the total became something like 50 per cent more than English
expenditures for research, viewed in terms of the discrepancy in national
income.

Perhaps even more important than state-supported science was the growth
of the practice of linking science with heavy industry in such a way that
the result rivaled the position of the universities. The movement had begun
prior to World War I in the creation of the Kaiser Wilhelm Society's

4. Ibid. The phenomenon heaped upon the so-called "Brain Trust" in the
United States very probably is based upon something more fundamental
than mere disagreement in politics. It is a nice illustration of the
basic distrust on the part of the practical business man for the so-
called impractical man of theory, although in this case most of the
criticism was directed toward the social scientist. It is significant
that no effort was made to distinguish between the practitioners of
social sciences and natural sciences. Note too that the popular comic
strips continue to depict the professors as "Prof., insta."

5. It is claimed that the Germans killed the men for every man they lost;
for every German aircraft lost, six enemy planes were destroyed.
Ibid., 172. These claims bear watching against Allied figures, partic-
ularly for the war in the air.

Institutes in Berlin, Göttingen, and elsewhere. These were founded by an association of business men, and demonstrated a solid appreciation of the dependence of industry upon science. The institutes were devoted to fundamental research, and they were not bound to the development of immediate industrial products. In addition, prior to the depression of 1931 large chemical and engineering firms were establishing research departments, lavishly equipped in a way which no university could approach. Furthermore, the staffs were not forced to rely upon immature researchers fresh from the training schools. Instead they attracted scientists of international repute who were expected to devote only part of their time to investigations which might prove immediately profitable to the firm; most of their effort went to researches of a fundamental nature.

Aeronautical Research

German aeronautical progress thus rested upon a superb scientific tradition. The powered flight first presented its technical problem in the years prior to World War I, when there was at hand a solid body of basic work in mathematics, physics, chemistry, and engineering upon which to draw. In the applied fields there was available a substantial body of information on the strength of materials, durability, and fatigue. It was not necessary to start from scratch. But various other types of information necessary for aviation had been developed in detail, simply because other technics had not needed them. Very quickly it was recognized in Germany that the practical and empirical methods used by Otto Lilienthal in developing his gliders were not adequate for aviation. There was the pressure of a series of fatal accidents and the knowledge that other countries were entering upon nascent programs of investigation in the field of aviation. But more important there was the initiative of the Kaiser, his brother, Prince Henry, and of Count Zeppelin, strongly supported by the Chancellor and the Prussian Minister of the Interior.

As early as 1907 Count Zeppelin stressed to the German Museum at Munich the necessity for aeronautical research organizations; in the same month the Kaiser, as Vot von Preussen, commanded the Prussian universities and technical institutions to do more for aviation. By December 1909 the idea reached the Reichstag for the first time when a group of representatives presented a measure seeking the establishment of a modestly equipped research institute for lighter-than-air work at Friedrichshafen, under Count Zeppelin. Litigious debates ensued in 1910 and 1911 as to the proper location, for Berlin was the choice of the Prussian Minister Industry because of its central location with respect to the entire country, and both the site on the Bodensee and that at Frankfort a/m were forced to yield to Berlin.

The project rapidly progressed. In June of 1911, Prof. Hermesell and Dr. Ludwig Prandtl produced a memorial for the project and a month later

the Ministry of the Interior presented to the Prussian War Ministry a plan by which 400,000 Marks would be furnished for initial construction while 200,000 Marks would be required for annual operations thereafter. The Kaiser maintained his interest in the proposal. After the army maneuvers of 1911 he demonstrated a lively interest in the advancement of aviation and regarded the erection of a German research institute similar to the French as urgently necessary.

On 20 April 1912 the research institute was founded at Adlershof, one of Berlin's suburbs. The new Deutsches Versuchsanstalt für Luftfahrt (DVL) thus became the focal point for the aviation interests of Germany. As founders, there were representatives of the Reich Ministry of the Interior, the Prussian War Ministry, the Secretary-General of the Kaiser Wilhelm Society for the Advancement of Science, the Society of German Engineers, and a substantial list of names representing the larger firms in German industry. To the first administrative council of DVL came men whose names and products already were known over the world, among them, Benz & Cie, Opel, Sparling, Adolf Raimer, and Robert Bosch.

The memorial directed to the Reichstag on the founding of the new Institute is of interest. It pointed to the great development abroad, as well as to the necessity for systematic research in order to improve construction and thereby prevent accidents. And it stressed that the advancement of aviation would occur through scientific and methodical investigation, that there must be a narrow and close cooperation between the DVL on the one hand and the universities, technical high schools, and state testing offices on the other. One additional point should be considered. In the final discussion over the establishment of DVL there was general agreement that the institute would serve a more useful purpose if it were to remain beyond the control of a regular governmental department. Thus DVL became a "registered association"; it was able to develop freely with a degree of autonomy not obtainable had it been created as a subordinate branch of an existing government agency. The state contributed roughly one-half of the original cost while the annual membership fee amounted to 5,000 Marks.

Among the tasks given to DVL was testing and setting up standards of safety within the aviation industry. In fact its first assignment was the technical direction of the royal competition for the best aircraft motor,

9. A. Baumer, "Die Deutsches Versuchsanstalt für Luftfahrt in Rahmen der deutschen Luftfahrtforschung," in Zeitschrift des Vereines Deutscher Ingenieure (VDI), Bd. 31, Heft. 17, 24, 'nr. 1937, 469. It is worth noting that despite the greater national interest involved, the citizens of Adlershof vigorously opposed establishment of the institute in their district.

10. A. Baumer, "25 Jahre DVL," 98. In this connection it should be stressed that the German Technische Hochschulen are much more advanced than any American high school. Those at Aachen and Berlin, for example, would rank more advanced engineering institutes than as high schools in the American sense.

11. Ibid. "Deutsches Versuchsanstalt für Luftfahrt," In Die Luftwacht, Heft. 11, Nov. 1927, 635. First director was Dr. Brandenburg and one of the first associates was Dr. Ing. Wilhelm Hoff, later a long-time director of the institute.
which involved the proof and testing of 65 motors within a year. Then in the fall 1913 came the first threat to its sphere of competence when the military announced its intention of establishing a special military research institute for aviation at Roberts. Immediately the director of DVL directed a memo to the Ministry of the Interior, pointing out that the thought behind erection of this new institute rested upon relatively primitive ground. He denied vigorously that DVL was an unproductive scientific-theoretical organization, apparently acting on the defense against some military leaders, who had determined to set up their own institute. He here for the first time in the history of German aviation technique appeared a sharp clash between advocates of scientific research and those who supported testing; in this case testing was designated as a proper field of activity for the military. On 26 February 1914, the Minister of the Interior informed DVL that the Russian War Minister would establish a close connection between the technical testing committees and DVL; the test results in the field of Military Aviation would be made available to Adlershof. The position of DVL was thus fixed as a handmaiden of the Luftwaffe.

"DVL was not the only research institute in existence prior to the war. As early as 1904 Dr. Rudolf Wurth, the University of Gottingen, constructed the first wind tunnel in Germany and by 1912 the aerodynamical laboratories at Gottingen and the Technische Hochschule at Aachen both were well established. But it was the task of DVL to draw together the work of all of these Institutes."

**World War I**

By the end of World War I the German government had spent approximately $32,000,000 on aeronautical research, a sum more than 10 times that spent by the British and better than 50 times the United States expenditure. The foresight of those who had brought DVL into existence in 1910 was more than justified. The Institute possessed some 70 workers, it had several motor testing stands, an electrically driven propeller testing installation, a wind tunnel of 76 cm. diameter with an air speed of 50 meters per second, and a collection of apparatus for the measurement of stresses. Furthermore already in two years of operation it had established its working procedures, and its tables of experience and analyses of the strength of materials for air material. Yes, the task jumped enormously.

In the early weeks of the war, DVL gave up part of its personnel to the army, apparently acting upon the assumption that the conflict would be of short duration. Soon however, it became necessary to recall some of the personnel.

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12. A. Necker, "25 Jahre DVL", 77. Apparently this was a recurrence of the old struggle between the "practical" military set and the "theoretical" scientists.

personal as the Field army, for an increasingly heavy burden was thrown
upon the Adler of Institute, as well as upon Göttingen. Now much of the
effort went to the testing of motors and hundreds of thousands of instru-
ments; at the same time VfL became an "Aircraft workshop," the center of
the German Air Force. It supervised the technical development of military
aviation, tested new types of combat aircraft, and throughout the war
managed to retain its original independent status.14 As a matter of fact,
Major Ladej, as representative of the Commanding General of the Luftwaffe,
insisted that the Army wished this form to continue. VfL's effect and in-
fluence upon the success of the Luftwaffe was fully appreciated. Twenty
five years after its founding, the Nazi chief of the technical section of
the Air Ministry paid tribute to the VfL and added that it was precisely
the field of aviation which demonstrated "how difficult it is to separate
the military air force power of a nation from permanent scientific invest-
igation." 15

Defeat brought an end to the intense activity of VfL. In 1913 it still
had some 100 personnel, of whom 11 were scientific engineers. But by 1922
the total had dropped to 15, only two of whom were engineers. The Versailles
Treaty had cut German aviation effort to a very low point, nevertheless the
RSC representative, visiting the country in the spring of 1920, gained an
impression that despite defeat, the Germans firmly believed in the future
of commercial aviation. 16 Research never did cease altogether. Down at
Göttingen, Prof. Prandtl and his assistants Dr. Albert Betz and Dr. Carl
Wielshammer had a new wind tunnel of 2 meters diameter which was described
by an RSC representative as the "finest arrangement I have seen so far in
any wind tunnel, including England." Already in 1923 there was talk of
constructing a new VfL, but funds were short. Not till 1927 was there a
permanent fund for the institute in the Reich budget, and from this time on
the director of VfL no longer was forced to justify his needs quite so

Meanwhile the work of investigation proceeded at Göttingen and at
Aachen. Prandtl at Göttingen had done much exceedingly laborious work in
the mathematics of the motion of compressible fluids; his theory of the
boundary layers was widely known. By 1921 Theodor von Karman at Aachen
presented a simplified momentum theorem for the boundary layer, and the
Aerodynamic Institute of the Technische Hochschule at Aachen became one
of the leading aeronautical research centers of Germany, along with Göttingen. 17

Throughout the post-war period prior to 1933, there persisted a shortage

14. "Die Deutsche Versuchsanstalt fur Luftfahrt," in Die Luftwacht, Sept. 11,
15. Ibid.; A. Remmker, "Die Deutsche Versuchsanstalt fur Luftfahrt in Namen
der deutschen Luftfahrtforschung," 470.
16. But not all aviation leaders appreciated VfL. Dr. Worrner, for example,
is reported to have testified to; juniors, on the other hand, appreciated
its value and took his problems to Adlerhof. L. T. Allen, "New Kings
J. L. E. acoll., "Modern Aerodynamical research in Germany," 6 Feb. 1930,
(came in NACA Intel. Libr.)
of funds; furthermore, the Reichsair displayed only a limited interest in aviation. It was the reduced number of personnel carried on while slowly the Institute regained its strength. By 1925 it had a force of 100; two years later it had nearly tripled, reaching 255. In the latter year 22 million marks were earmarked for an expansion program but the project was delayed pending a selection of the site. It was difficult to convince the Reichsair of the long-term value of the research Institute but the need increased and an pressing was the lack of equipment that finally it was postulated that specific research problems should be farmed out to the United States which possessed more adequate facilities.

Throughout this period, IV, maintained its close relations with industry and the technical institutions, particularly Wittingen and Aachen. IV did not duplicate their work. Instead, it tried to systematize their research and bring them to concentrate on the more important problems. Then too much of its work consisted in testing new inventions. By 1931 IV was the examining institution of German aeronautics, acting under the authority of the German Transport Law (aerial). Its jurisdiction included the certifying of types, examination of construction and design, and subsequent revision of licensed aeronautical construction.

Although IV was not founded as a state institution, gradually the influence of the non-military members of the association lagged behind that of the leading members of the Reich Minister of Communications. In March 1933 a renewed effort was made to transform the Institute into a regular governmental department but before it could be decided, the Nazi revolution occurred.

The Nazi Revolution

When the Hitler forces seized power in January 1933 IV had a force of 460 personnel. Strangely enough it was decided by the Nazis that the Institute should remain outwardly the same semi-independent character with it had held since 1912 for they believed that in this manner it would be easier to preserve the close relationships between research and industrial development. Then too there was some doubt that scientific research could be furthered by the establishment of an authoritarian institute subordinate to a government agency, as Major Sievert had pointed out during the World War I.

19. This phase of its activity caused some industrialists to advocate that the Institute should be placed on an official status; thus it would be easier to entrust trade secrets to the IV for examination. Opina; address at the Annual Meeting of the Forschungsge meinschaft fur Luftfahrt, June 1923, in ACA Intell., 4th.
It was only natural that in mobilizing the resources of the state for war, the Nazis should pay close attention to the structure of their aeronautical research institutions. When Hermann Göring became Reich Minister for Air on 5 May 1933, there immediately began for NL an enormous expansion of facilities and tasks. Its administrative structure was overhauled. The gap between NL and the Luftwaffe was narrowed by bringing the new president of NL's council, Dr. Ing. Oppenberg, and the new director, Dr. Ing. P. Seewald, into close relationship with the two a. l.o.s. of the Technical Section of the Reich Air Ministry, Maj. General Himmler, and Col. Amt Bd, as well as State Secretary Aviation General Wolff and the then chief of the Luftwaffe Administrative Office, Lt. General Albert Schenk-Knenring. Officially NL was under a committee of nine members, all named by the Reich Minister for Air.

It should be noted, and it was quite in keeping with German attitude toward science, that the first step taken by the Nazis was not to build aircraft, but to expand their research facilities and to adopt a long-range research program. Significantly, Göring felt that the research could only be accomplished effectively if all branches fed into a single unified, policy-making head. Rapidly he expanded aeronautical research; lack of funds was no longer a problem. Work was begun on a magnificent and elaborate series of structures at Adlershof to provide NL with the most modern equipment. By 1935 it was nearly completed, and could be described by E. T. Allen, a visiting American aeronautical engineer, as "now larger and more elaborate than our Wright Field plus all of our Navy development work, plus all of the Bureau of Standards devoted to aviation." It had become all this, and a NASA as well; with the added advantage that it could operate with "apparently unlimited appropriations." Science now could plan full-scale wind tunnels, laboratories, research factories, with no regard either for the cost or for the political opposition. Allen found that NL had gone further into flutter work than American laboratories, while two years later the research director of NASA, Dr. George W. Lewis, discovered that German factory technique appears to be the equal or superior to that of the United States and their costs are less." Dr. Lewis found NL alone using some 1,400 people in its elaborate installations. New wind tunnels were under construction at several points. Göttingen now had one measuring 15½ by 24 feet, while the new NL atmospheric tunnel was 16.4 x 29.0 feet. The close relations with the other institutes and with industry were maintained even more rigorously, and NL even operated a school for test pilots in an effort to bridge the gap between theory and practice.

The Reich Minister could order the construction of laboratories, but the procurement of an adequate body of trained personnel was another matter. Realizing the very close connection between educational institutions and technical air research, Göring directed the Minister for Science and Education

23. E. T. Allen, "Report of German Trip," 3 Nov. 1935. This is a confidential report submitted to NASA by him upon his return from Germany in 1935.
to give special attention to the needs of aviation. In 1933 he had proposed that three new special facilities for aviation technique be set up in the Technische Hochschulen in Berlin, Braunschweig, and Stuttgart. He believed that air research occupied a unique position, that the natural science background of the new aviation technique had been almost exhausted. Too much of what had been achieved was the result of trial and error. A new approach was in order, one based upon careful scientific investigation. Hence existing training facilities were expanded, while new ones were established in the years following the Nazi assumption of power.

Although the new AVL overshadowed all other institutes, the factories themselves each maintained extensive laboratories and research facilities. Much of the work in the plant laboratories initially was devoted to testing the strength of materials, fatigue tests of completed structures, and removal of "bugs" from the completed product, but on occasion special problems were farmed out to AVL or to Aachen, or to some other institute. Or the firm might send a number of its own personnel directly to the institute where they could work directly with the permanent research scientists. The reverse occurred as well. Messerschmitt, for example, worked very closely with Gottingen, as well as with AVL, while the aerodynamical institute at Aachen was turned over almost exclusively to the testing of Heinkel designs, with a body of some 20 Heinkel engineers attached to the institute for long periods of time. At the same time (1936) Junkers maintained over 20 project engineers at Gottingen. Heinkel had installed a single-return tunnel by 1936, while after the outbreak of the war many of the factory laboratories were greatly enlarged and engaged in more fundamental investigation. Dr. Dornier established a new research division for propeller work at the Dornierwerke on Bostensee; Messerschmitt had K. Lippisch working on tailless planes, and the A.E.G. had made good progress on controllable pitch propellers.

Goring faced the problem of coordinating all these research organizations, of overcoming the danger of duplication, overlapping, and waste of talent. The answer lay in the Aeronautical Research Association (Die Vereinigung für Luftfahrtforschung or VFL) created on 28 April 1933, an organization which soon embraced all aeronautical and experimental work in Germany. It consisted of an advisory board, branch committees, and subcommittees devoted to specific problems. Oddly, there were no permanent members; the only permanent elements in VFL were the council, the clerical staff, and the chairman of the boards and committees. All other scientific and technical personnel were merely invited from time to time to collaborate only on such subjects.

25. Address of Reichsm minister for Air, General Goring, at opening session of the Deutsche Akademie der Luftfahrtforschung, 1 Apr. 1937 in Jahrbuch 1937 der deutschen Luftfahrtforschung, 3-5.
as were pertinent to their own respective fields of investigation. Chair-
men of the committees were outstanding specialists chosen from scientific
and "practical" circles, selected exclusively for their ability to detect
and develop promptly the needs of their branch. As chairman of the com-
mittee Göring even preferred men who were not themselves directing research
work, believing that they would thereby guarantee a more neutral treat-
ment of the problems before the committees. On the other hand, the scientific
personnel of the committees generally were members of the various aero-
nautical research institutes of the country; furthermore, care was taken
to assure that representatives of both government and industry were re-
presented at all committee meetings. 29 For the purpose of enabling an
exchange of information and experience between industry and science, tech-
nical discussions and lectures were held at larger meetings of some 50
members (larger, that is, than the small Vf. sub-committees where preparation
of reports is accomplished.)

Each sub-committee held two such large meetings annually, and each was
devoted to but one general subject; it was held at such locations where the
lectures could be supplemented by practical demonstrations. Normally, per-
sonnel of the research laboratories would be summoned to these meetings,
but it was customary to invite capable young university students to attend,
as well as interested foreigners. 32

Here then was a central clearing house for the entire German aero-
nautical research effort. Once established, Vf. was able to direct every
phase of research, for it brought into direct contact with government and
military the representatives—and researchers of the universities, the
technical institutes, all private experimental laboratories, all factory
research, and the new enormous Vf. Through its committees it could observe
the progress of investigation in every field; it could assign a problem to
that agency believed to be best equipped to solve it. And if a given pro-
blem was moving slowly, it could throw increased support to move it ahead.
Vf. thus was able to initiate research for the entire German aviation
industry as well as for the Luftwaffe. 33

Another agency established by Göring as a necessary adjunct to research
was the Office of Aeronautical Intelligence (Zentral-Referat fur Wissenschaftliche
Erkenntnisse uber Luftfahrzeugentwicklung, or ZfB), created on 27 March 1933.
Its function was to serve as a central agency for the collection of all
reports concerning aviation, including the results of research and experi-
mental work. ZfB became the official depository for all aviation information.
Operating under the management of Vf. at Berlin, it classified and dup-
licated reports for subsequent dissemination to industry and the operators
of aircraft. 34

29. Ibid. As might be expected, the Air Ministry was well represented.
30. Ibid.
31. Ibid. 4. Braemker, "25 Jahre Vf.," 103; V. T. Hill, "Report of German
Trip," 1 Nov. 1935, 2.
VLF was not a public organization; certainly its technical activities were not made public and its membership was limited to those specifically invited by the Air Ministry. To provide an organization on a less restricted basis, the Lilienthal Society was established. Unlike VLF, this agency was open to all who could meet the requirements of admission and afford the annual subscription. But here again the organization was coordinated with the older Nazi creations; its patron was Goring and its senate consisted of the Council of the Association for Aeronautical Research (VFL) plus technicians from industry and the various institutes. It too worked out research programs, and provided medals for outstanding achievements. 33

At the apex of the hierarchy of honor in aviation stood the German Academy of Air Research (Deutsche Akademie der Luftfahrtforschung), created by Hitler's decree on 26 July 1936 for the express purpose of recognizing the technical and scientific leaders in the field of aeronautics. Although the laws of the Academy stress the value of the research activities to commercial aviation, a survey of the membership is significant. President in 1933/39 was Goring, Commander-in-Chief of the Luftwaffe, while the Vice President was Col. Gen. Erhard Milch, general Inspector of the Luftwaffe. Moreover as patron (honorary) members was the top military hierarchy of the Luftwaffe and its AA division, including Hugo Stinnes, Ernst Udet, Albert Kesselring, and Hans Jeschonnek. A maximum of no more than 60 "ordinary" members was permitted, to which were added 100 corresponding members. But among the ordinary group appeared the creme de la creme of German air researchers and designers; among them Albert Betz, Carl Cranz, Max Kramer, Ernst Heinkel, and Willy Messerschmitt, with Ludwig Prandtl occupying a special position of honor. 34

Thus the Nazis overhauled the structure of German aviation. By 1939 they had created an enormous air industry, resting upon a network of closely coordinated research institutes, and fed by a growing number of technical training schools. An assessment of their scientific achievements lies beyond the scope of this paper, or the capacity of its author. It is sufficient to indicate the impression which their equipment left upon foreign observers. Charles A. Lindbergh's enthusiastic reactions are well known, as are those of Al Williams. 35 Perhaps more valuable are the comments of the English and American engineers who observed the equipment and its product immediately prior to the war. For example, at the Paris Aero Salon of November 1938 DVL unveiled a brilliant array of testing devices which astonished British engineers. In 1933 it was estimated by an English observer that Germany's aeronautical research facilities consisted of a dozen establishments equal to the combined facilities of the NACA at Langley Field, Wright Field, and the Naval Aircraft Factory. 36

34. Introduction to _Jahrbuch der Deutschen Akademie der Luftfahrtforschung 1938/1939_.
35. The complete failure of these two flyers to comprehend the significance of what they saw has led to some doubt as to validity of their comments on European air developments in general.
More important was the product of the German aeronautical laboratories. As an indication of the energy devoted to research, the Journal of the German Engineer Society in 1932 carried a list of over 1,300 engineering research projects exclusive of chemistry, covering 26 pages of fine print; many of these aeronautics and 145 projects were devoted to thermodynamics alone. 37

When the Yearbook of German Air Research for 1937 appeared, in the words of its English reviewers, it was nothing less than an "incredible volume" and "leaves one gasping---not just because of its size or its contents, but because of its implications." Here was a volume of more than a thousand pages, crammed with technical papers and reports by researchers at DVL, in the numerous Institutes, as well as those from the laboratories attached to Dornier, Heinkel, Junkers, and Focke-Wulf. 38 At a time when rocket and jet propulsion occupied a position in the United States and England somewhat akin to alchemy, when the Rocket Societies were generally regarded as "too strange to be tolerated but not accepted by polite science," Prof. Wilhelm Jost of Leipzig brought out in 1939 his monumental treatise on jet propulsion. Nothing like it has yet appeared in English. 39

The scientific background was at hand in Germany; the Nazis merely translated it into action. By establishing a vast system of dominating bureaucracy with an "unbelievable enthusiasm for matters aeronautical shared by the military and the civil population alike," 40 they were able to mobilize the research talent of Germany. The test of war proved the merit of the product. Two of the fighter aircraft, the ME-109 and the FF-190, have ranked among the world's best combat planes almost throughout the war, while the JU-88 has been a superb medium bomber. The fact that the Luftwaffe lost its air war is not necessarily a reflection upon the German aerodynamicists and aeronautical engineers; the errors were made by politicians and military men in the field of strategy, a field regarded as outside the competence of scientists.

There was a negative side to German aeronautical research under the Nazis, just as in every other scientific field. They had mobilized all research talent, but only that talent which was of the acceptable political persuasion or proper racial strain. All science had been hitched to the national bandwagon; creation of the National Research Council on 16 March 1937 did for all research what VLF achieved in the field of aviation. The

39. Explosions- und Verbrennungsvorgänge in Flasen, Dr. sc. nat. Wilhelm Jost, Berlin, 1939. Jost was a professor in the Physical-Chemical Institute of the University of Leipzig. His volume includes 518 pages of text, is jammed with graphs and formulæ, and represents the first major treatment of this subject.
preamble to the law establishing the Council frankly stated that now scientific investigation assumed the task of reaching goals "in which the existence of the whole nation depends." Science would be coordinated with the Four Year Plan. Moreover it would be practicalized, particularly the technological sciences. Doubtless this proved stimulating for a time; directors of laboratories—rarely deeply concerned or fully informed over the trend of politics—were happy to receive the limitless grants now provided. Yet their work was based upon the patient labors of others who had pioneered in fundamental investigation in physics, mathematics, and chemistry. And the Nazis had rooted out some of the country's ablest researchers in those fields. The full long-range effect of this interdiction of the laboratories to the politically and racially unreliable cannot yet be measured; certainly the outcome of the war has upset any opportunity for an objective assessment. But there is evidence that the Nazis themselves were aware of the danger to the future progress of the country as they watched the declining numbers of fresh students in the technical fields. In 1937 politics made a slight retreat. 42

But regardless of the temporary shifts in national politics and the political value of "practicalization" there seems to have been no decline in respect for fundamental scientific research. Dr. Friedrich Seewald, Director of NWI, was severe in his criticism of what he called the scientific "dainty" i.e., the "monkey-wrench" inventors and tinkerers, only a small part of whose labors are ever useful. He recognized that as often as not the influence of patient scientific research is lost in the final product, citing Prandtl's theory of induced drag as an example, but when the research is planned, it is always useful, even though remote. As Werner von Siemens neatly phrased it, "Science often pours out its richest blessing upon life when it seems furthest removed from it." 43

This seems to be a reasonable statement of the German attitude toward the investigation of remote and obscure problems of science, for the German state does not shy away setting its scientists to searching for the needle in the haystack. Furthermore, it rewards the successful searcher with public esteem on a scale never attempted in the western democracies and equalled probably only in the Soviet Union.

42. Ibid. In the spring of 1937, Carl Bosch was appointed director of the Kaiser Wilhelm Society for the Promotion of Scientific Research. He is reported to have resisted excessive political interference with the scientists under him. The Nazis had good cause for alarm; in the period 1932-1937, the number of students in mathematics and natural sciences had dropped 64.6 per cent, exceeding the loss of any other field.
43. Quoted in Friedrich Seewald, "Forschung als Grundlage des technischen Fortschrittes," in Jahrbuch 1937 Der Deutschen Luftfahrtforschung, 16.
Aeronautical Research Institutes in Germany, 1937.

1. Deutsche Forschungsanstalt für Segelflug e.V. (DFS) Darmstadt. 
   Director: Dr. phil. Walter Georgii

2. Deutsche Forschungsanstalt für Luftfahrt e.V. (DFL) Braunschweig. 
   Director: Dr. phil. Gödeck

3. Deutsche Versuchsanstalt für Luftfahrt e.V. (DLR) Berlin-Adlershof. 
   Director: Dr. Ing. Friedrich Geismar

4. Aerodynamische Versuchsanstalt Södingen e.V. (AVA), in the Kaiser 
   Wilhelm Gesellschaft zur Förderung der Wissenschaften. 
   Director: Dr. phil. Ing. Albert Betz and Dr. Engelbracht. 
   Chairman of the Council: Ludwig Prandtl.

5. Flugzeug-Forschungs-Institut Oberpfaffenhofen e.V. (FO) 
   Oberpfaffenhofen, Oberbayern. 
   Director: Prof. Dr. rer. nat. Max Beckmann.

6. Aerodynamisches Institut der Technischen Hochschule Aachen. 
   Director: Prof. Dr. Ing. Carl Rieselsberger.

7. Flugtechnisches Institut, Technische Hochschule Berlin. 
   Director: Dr. Ing. Herbert Wagner.

8. Institut für Luftfahrtmesstechnik und Flugautomatik, Technische 
   Hochschule Braunschweig. 
   Director: Dr. phil. Karl Hahnoppe

   Director: Dr. Ing. F. S. Schröder.

10. Institut für Aerodynamik und Flugtechnik, Technische Hochschule Hannover. 
    Director: Dr. Ing. L. Rötzell.

11. Flugzeug- und Luftfahrt- und Versuchsanstalt, 
    Ettelfingen bei München. 
    Director: Prof. Dr. rer. nat. Max Beckmann.

12. Flugtechnisches Institut an der Technischen Hochschule Stuttgart. 
    Director: Dr. Ing. Hermann Bendlung.

13. Forschungsinstitut für Kraftfahrwesen und Fahrzeugmotoren an der 
    Technischen Hochschule Stuttgart. 
    Director: Dr. Ing. W. Hildbrandt.
### Additional Institutions Which Offer Instruction in Aeronautics

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RESEARCH AND DEVELOPMENT IN RUSSIA AND THE SOVIET UNION, 1914-1939

Russian aeronautical science in the prewar years was more a promise than an achievement, for it rested on nothing like the solid background extent in Germany or England. Under the Czars Russian science in general labored under severe handicaps; it had been barely tolerated, and there was always about it a suspicion of liberalism. It had been fostered only to an extent barely sufficient to provide minimum support for the army and the civil service and to present a front to western Europe. Most of the scientific apparatus was imported, and research was heavily reliant upon French and German work. Yet pre-Soviet Russia did produce a number of notable scientists, including Mendeleev (chemistry), Borodin (aldehydes), Pavlov (biology and medicine), Sikorski (aeronautics), Metchnikoff (zoologist and bacteriologist), Lobachevski (mathematics and statistics), and Ipatieff (petroleum engineer). However strong or weak Russian science was, the revolution and ensuing civil war made it worse, for the personnel were scattered over the globe. Thus the Soviets faced the double task of creating a Soviet science and technique, while reconstructing the country.

In the field of physics, progress occurred exclusively in the universities and one or two of the technical high schools; for most of the 100 working physicists, research was subordinated to teaching. The research they did accomplish was, for the most part, not original. Instead it seems to have represented variants of investigation already under way in France and Germany; moreover it was kept free from any relationship with technology.

The performance of Russian weapons and military equipment in World War I needs no elaboration in the current discussion. There was relatively little contribution from organized scientific research. In the field of aeronautics, the very small air service had among its brightest lights Seversky and Igor Sikorski, but there is little evidence to indicate that there were any facilities available in any way comparable to Germany's ZVRL. Yet the Russian government had spent the equivalent of $12,000,000 on aeronautics from 1908 to 1913.

Russian interest in basic aeronautical research centered around the work of W. E. Joukowski of the Moscow Technische Hochschule. Here, prior to the war, a flying club installed its own primitive laboratory, supported by the school, and was able to construct two wind tunnels. One of these was designed by Joukowski, while the work was supervised and executed by A. N. Tupolev, who later designed several of the Soviet Union's better aircraft. By 1910 the club exhausted its funds, whereupon the laboratory carried on under the support and direction of the technical school. During the war this small laboratory was active although it accomplished very little experimental work; most of its energies went to stress analysis.


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Russia's aviation was practically wiped out as an aftermath of the revolution of 1917. The Soviets were forced to start from scratch, for by 1921 not much of anything was left. As early as 1920 the new USSR had begun to reorganize and re-equip its aviation under German supervision. Residue war stocks were purchased from Italy, Great Britain, France, and from Fokker, who now had moved to Holland. The Germans, in an attempt to escape the restrictions of the Versailles Treaty, sent many of these able designers to Russia, where the Russians gained an easy access to German methods. Junkers had established a plant at Eddi in 1921-1922 while subsequently Heinkel, Dornier, Rohrbach all were called in. Thanks to this aid, aviation received a new impetus; aviation and engineering personnel acquired training and experience not otherwise available. But the greatest advance occurred in industrial efficiency, rather than in native designing skill, with the result that it remained necessary to rely heavily upon foreign designs.

Meanwhile, in an attempt to emancipate itself from such reliance, the new Soviet state established a center for aeronautical research. This was the Central Aero-Hydrodynamics Institute (ZAGI), founded in 1918 on the initiative of Prof. M. S. Zhukowski with 36 of his students and co-workers. After the revolution, the experimental and calculation section of the old Joukowski laboratory had been transferred to the experimental institute of the division of highways and communications. Now in 1918 this section provided a nucleus for the new research institute, which was incorporated in the scientific and technical section of the Superior Council of National Economy. Henceforth the Joukowski laboratory became an integral part of ZAGI, although it was forced to continue its activity at the Moscow Technische Hochschule until ZAGI's new installations were ready in 1927. Until 1923 ZAGI showed little activity. Personnel were scattered and work was not resumed at all prior to 1922. About this time the theoretical work of Prandtl (Göttingen) became known to the Russians and necessitated the modification of the existing wind tunnels. A new temporary tunnel was installed in 1923 and work was initiated on the design of an entirely new aerodynamical laboratory for ZAGI.

At this point it is of some profit to examine the basic dogmas of the Soviet state in its relationship to science per se. Soviet science is completely integrated with the state; its development proceeds according to an over-all plan, and in theory it is encouraged more than in any other state system. There is, of course, no basic difference in the techniques and

7. Bernal, Social Function of Science, 224; J. J. Crowther, Soviet Science, (1942 ed.), 16. It should be added that if funds for research in the United States should exceed the amount expended similarly by the U.S.S.R., the basic premise still holds, Soviet theory supports science officially; the democratic theory is much less interested in research.
methods of research galvanometers are the same at Langley Field, Farnborough, or Moscow. The difference lies in the contrast between Soviet social philosophy and that of the Western democracies in the conception of science's role in the organization of society. For the Western states (including the United States) do not receive science as a necessary part of the social organization. Their legislative bodies do not in theory consider science and technology as a necessary part of the social organism.

In practice, obviously democratic states do recognize science, since they establish state research laboratories and institutes and subsidize private research. But these are normally achieved only after lengthy debate as to the wisdom of expending funds on institutions where "long-haired" physicists may putter around endlessly without ever coming up with an improved bathtub or lawn mower—which are the things that really matter. In Russia, on the other hand, rests its case officially on the necessity for physical and biological investigation. Natural science is an organic part of Marx philosophy. Consequently a social system founded on his principles must be founded on technology and science. Marxists have always conceived of society "thoroughly permeated by science, one in which science becomes a corner stone of education and culture." Therefore to the Soviet government the scientist is as much a natural resource as the Caspian oil deposits, he must be nurtured and suitable institutions must be provided for him in which he may exercise his talents.

One more factor affects the labors of Soviet investigators. In theory their researches are not conducted within the framework of a corporate enterprise whose goal is immediate and profitable sale upon the open market. Thus it is claimed that free rein is granted to what is understood as fundamental research. There is no need for the rapid production of tangible results. The full resources of the state are thrown behind whatever fundamental research is necessary.

With this union of politics and science as its dogma, the U.S.S.R. proceeded as rapidly as possible to organize and direct the scientific energies of the country. Science was planned in such a way that it would distribute available resources between the various branches and institutes for scientific research in a proportion calculated to produce the best results both from the point of view of immediate production and from the longer-range viewpoint of benefit to Soviet science and the common welfare of the state.

8. Crothers, Soviet Science, 19; Bernal, Social Function of Science, 223. In the United States witness the relative stature in public esteem of Dr. Charles Kettering as compared with that of L. G. Lawrence. The former produces gadgets for motor cars and his name is almost a household byword. The latter is a researcher in a fundamental field, and although a Nobel Prize winner, he is relatively unknown outside his own profession.

9. Ibid. 16. What happens to those researchers who fail to meet a pressing need of the state is not clear. In the purges of 1937, it is reported that many scientists and designers were liquidated, among them A. V. Tupolev, one of Russia's foremost aircraft designers. It is assumed that these individuals were removed on grounds of political unreliability, rather than for failure to produce, although the latter might easily be construed as one phase of the former. In any case, here only theory is under discussion.
To survey the problems facing science is the task of the Academy of Sciences, directly responsible to the Supreme Council of the State. It continually studies the condition of the country, surveying in collaboration with the several commissariats the condition of roads, national defense, health, etc., then reporting to the State Planning Commission, which uses the Academy's findings in preparing a unified plan for the national economy. Prior to the current war the Academy possessed about 40 research institutes of its own, but this figure represented only a small portion of the total. More than 800 others were controlled by the various commissariats. Thus the academy became the administrative focal point of all scientific activity in Russia. It is the agency which parcel's out research projects to factories, to institutions within the commissariats, and to its own laboratories, which engage primarily in work of a fundamental nature.

Recognizing the close affinity between the construction and operation of a machine industry on the one hand, and scientific research on the other, the Soviets attached many of their best institutes to the Commissariat of Heavy Industry. This department maintains laboratories which are organized in a division known as the Scientific Research Sector (NIS) of the People's Commissariat of Heavy Industry, an agency which is the nearest parallel to the British Department of Scientific and Industrial Research. It finances many of the best known laboratories in Russia, among them the Physico-Technical Institutes of Leningrad, Kharkov, Sverdlovsk, and Dnepropetrovsk, the Karpoz Institute of Chemistry at Moscow, the Optical Institute of Leningrad, and the Institute of Chemical Physics at Leningrad. All of these institutes prior to the war were engaged in fundamental research in the physical sciences. Until 1936 NIS included many laboratories concerned with the application of physical science, but thereafter these factory laboratories were placed under the direct control of the industries with which they were connected, although their programs of research all were coordinated through NIS. The larger institutes with the Commissariat of Heavy Industry were not allowed to attack small scale problems which might be solved in the plant laboratories. Coordination of research within NIS is achieved through a series of about a dozen committees, each with 10 to 15 members. These committees also determine the allowances for books, scientific and monographic literature, and they arrange for conferences on research.

In the larger sphere, coordination of all Russian research is achieved by the Academy of Sciences. Each subordinate organization is held continually responsible for transmitting fresh information up the line to permit broader utilization of each discovery. Under normal conditions each institute submits a research plan as an annual basis, although a strong effort was made to block out many of the programs to cover the Third 5-year Plan (1938-1942). On a given date all the institute directors are summoned; in collaboration with the State Planning Commission and the Academy of Sciences, the proposals of

the various institutes are discussed and coordinated. Costs are checked by state accountants and are compared with the amounts allotted for research. Rarely were costs not covered. Funds have usually been provided to cover the needs of any project the laboratory was able to undertake. 12

It should be stressed that the U.S.S.R. has integrated all its research centers. The universities and technical training schools each has its own laboratory which is closely linked with those of the Academy. Perhaps of even greater importance are those attached to industry. These are concerned primarily with problems connected with the industry and they include some of the country's ablest scientists. There are literally hundreds of smaller laboratories attached to smaller plants and to the field agricultural stations. The pattern of operations is hierarchial. Industry feeds its problems to the technical institutes; if not solvable at this level, they are passed on up to the Academy for a more fundamental attack.

The Soviets attempted to implement the Marxist dogma that science must thoroughly permeate all society. They have not stinted themselves in providing financial support. In 1934 they granted nearly one billion rubles for scientific research, which, at official rates of exchange, was nine times the British expenditure and amounted to 1/10 of 1% of the national income, as against a British contribution to science of 1/20 of 1%. 13

Even allowing for discrepancies in exchange values, there can be no doubt that Russia was preparing to permit free play for the researchers within the framework of her philosophy. In her schools science was taught from the earliest grades, while in the universities it was "extremely thorough and effective." And among her people there prevailed a vast popular interest in scientific books. Translations of foreign scientific works often out-sold their native editions in the country of origin. 14

That all this will add up to can not be assessed at present. The first Soviet generation had not yet been granted time to contribute to world science before the war engulfed it. But as until the outbreak of the war, J. J. Ber-sal, the British physicist, found that Soviet science was quite uneven in quality. There were high achievements in some fields, such as animal psychology, plant and animal breeding, agronomy, geology, and certain branches of mathematics. But in others—alas significantly—in the technical sciences, such as chemistry, he concluded that the Soviets still lagged behind. 15 It is highly probable that they will not catch up to a level with the western nations. Certainly they have demonstrated a keen appreciation of the requirements of the technological age in which they live.

It is within the above framework that Russian aeronautical research is to be examined, that is, on the very limited scale which the Soviet government has permitted. For only the most fragmentary information emerges from

12. Bertram, Social Function of Science, 44.
13. Ibid., 51, 224, 226.
pre-war Russia regarding her aeronautical investigations. There were and are almost no official publications on the subject. Those few that were available were usually colored by the political persuasion of their authors; while the resident military attaches in Moscow found it very difficult to obtain reliable information. 15

Brain center of the aviation industry was, and presumably still is, the Central Aero-Hydrodynamics Institute of Moscow (ZAGI), which in 1936 had four large wind tunnels, plus a number of smaller ones, and comprised four sections devoted, respectively, to engines, materials, hydraulics, and aerodynamics. Administratively, ZAGI was under the Commissariat for the Aviation Industry, which controlled within the same body control over both production and research. In addition there are the Central Institute of Aviation Engines (ZIAM), and the All-Union Institute of Aviation Materials (VIAM), which are in charge of testing and accepting new equipment. ZIAM has a factory for production of experimental types just as ZAGI has one for the construction of new designs in completed aircraft. Other laboratories are scattered about the country. Down at Sevastopol the naval Air Arm operated a research institute; the Research Institute of the Civil Air Fleet comprised four independent establishments at Moscow, plus one at Kiev, and another at Kharkov; and the Red Air Force maintained a special institute devoted primarily to navigation problems. 16 The list here makes no attempt at completeness. Too little is known about the development of air research in Russia. Occasionally in the pre-war years reports filtered through indicating further energy in research. Late in 1937 it was believed that the Commissariat for the Armament Industry planned to erect a large aeronautical testing center near Omsk for which 21 million rubles had been set aside. Four years later ZAGI's installations were rebuilt and expanded, and apparently were in place in time to contribute to the air effort of the Soviet Air Force; it was described as "elaborate and huge." 17

In view of the dearth of basic information on Russian air research, any assessment of its value is beyond the ability of the author. Prior to Russia's entry into the war in 1940, much of the opinion regarding the Red Air Force, which we may reasonably assume embodied the best of Soviet research, was often affected by the political prejudices of the observers. In 1936 Soviet military aviation was praised by Pierre Cot, former French Air Minister, as the best in the world, whereas Charles Lindbergh regarded it as the worst, and Al Williams, observing the Russian exhibits at the 1936 Paris Salon, did not regard it as worth his time to go to Russia to see for himself. Fortunately there were objective minds, men who reserved their judgment. 18

Dr. George W. Lewis, director of research of NACA, visited ZAGI's installations in 1935 and reported upon his return that equipment was poor. The research he observed seemed "preliminary", while the wind tunnels, of which the largest was 16 x 12 feet, appeared to be poorly designed. He found 3,500 employees in the experimental shop, a staff handling all design, stress analysis, and flight testing for the Russian Army and Navy, in addition to carrying on their own research work. On this occasion the director, N. I. Pavlov, stated that lack of trained personnel represented the primary problem, which would indicate that the technical schools had not yet been able to provide the technicians.

Prior to 1935 Russia had relied heavily upon German models, but in the following two years a shift occurred away from German to American designs. Russian engineers inspected many foreign plants and concluded license arrangements with Hispano-Suiza, Gnome et Rhone, and Curtiss (Cyclones). For aircraft they went to Martin, Douglas, Seversky, and Consolidated. As late as 1941 it was reported that her fine I-17 fighter had followed the Spitfire rather closely, while her ZK-B-26 was a copy of the Martin 139 twin engine bomber. It was apparent that her research laboratories had not yet fully shaken off their reliance upon foreign designs at the outbreak of the war. Yet there were signs that the advance was considerable. German Condor Legion pilots spoke very favorably of Russian fighter work in Spain during the Civil War, and the Russian IL-2 or Stormovik was a superb weapon against the Germans in 1941. It is not improbable that the new generation of designers in Russia eventually will be able to complete the process of emancipating her aviation from reliance upon foreign design.

20. Interavia, No. 770-771, 27 June, 1941
Aeronautical research and development in Italy since World War I has been a reflection of the political and economic condition of the country. An account of research and development which ignored that fact would be practically valueless; the factual data without its context would be highly misleading. The decade that followed the Armistice of 1918 was marked by the coming into power of Fascism, the firm establishment of Fascist control within Italy, and the stabilization of Italy's internal position. This was an era of comparative world peace and disarmament, marked by a series of international agreements designed to obviate war. While in many countries this was also a decade of economic prosperity, in Italy it was one of economic stabilization upon a basis which seemed to implicate a slowly declining standard of living. Restricted in the export of surplus population and commodities as well as in access to raw materials, Fascist Italy performed a large part of its attention to the fostering of self-sufficiency in food and clothing, the distribution of employment, and to the development of manufactures to which foreign markets were not closed. Concurrent with this attempt at stabilization of the internal situation there was followed a program designed to win prestige for the nation and its revolutionary government among the nations of the world.

During the next decade, from 1929 to 1939, world-wide economic depression and increasing international tension marked by acts of imperialism were accompanied in Italy by accelerated economic activity and a growing chauvinism that was the product of skillful government propaganda. Abandoning the method of conciliation and amicable adjustment of international differences, both Italy and Germany adopted with considerable success international policies based upon the use or threat of force. In order to carry out such a policy it was necessary that the country be reorganized economically, psychologically, and militarily. These phases of the history of the "period between the wars" are reflected in aeronautical research and development in Italy.

After the Armistice of 1918, as a result of poverty, internal political unrest, and intense pacifistic sentiment the Italian Aeronautical Corps was reduced "to a pitiful state of numerical weakness that, but for the sadness of it, it might be termed a reductio ad absurdum." Until 1922, Gen. A. Guzzoni wrote. "Aeronautics were practically abandoned, for reasons of economy and because the firms had stopped all experimental work owing to lack of finance. There were also political difficulties, as workers refused to cooperate in the building of engines for airships, considering them war organs." Some attempt was made to develop civilian aviation under a Directorate of

1. Prepared by Dr. Joseph Reither, APIHI, March 1945
Civilian Aviation, since Italy was too poor to undertake the development of both civilian and military aeronautics, but it was not until the Fascist government was strongly enough established to tackle the problem that Italian aeronautics was given a new lease on life. This occurred in 1923.

In January the new cabinet instituted a reorganization of the whole field. Mussolini headed the new High Commission of Aeronautics, the chief subdivisions of which dealt respectively with civilian and military aeronautics. Before the end of the year the Italian Air Force was made independent of the Army and Navy. Incentives were immediately given to the development of new aircraft and engines. Five million lire was set aside for an aero-engine competition with prizes up to one million lire to go to companies competing in the French aircraft engine competition. A prize of one million lire was offered for a trans-Atlantic flight and a prize of 100,000 lire for a Rome-Verona flight. Many Fascisti Aviatori were created by the Fascist Party in the principal towns to back up the government's effort to restore Italian aeronautics. 3 The prizes mentioned were designed to encourage research, experimentation, and development on the part of the aircraft industry in particular.

The chief experimental stations under the Air Ministry were the station at Montecelio, the seaplane station at Vigna di Valle, the armory school at Fucino, and the airship station at Ciampino, all of them in the vicinity of Rome. Experimental testing was also conducted by the Photographic Section and the Electric and Radiotelephonic Section. However, until the creation of the Guidoni experimental station in the early 1930's, the government units confined their activities largely to service testing of new equipment except in the lighter-than-air field.

As was inevitable, experiment and research proceeded slowly. But the numerical expansion of the air force was begun at once. By the end of October 1923 25 squadrons were equipped with newly built machines of old types. In June, the reorganization of the aerial arm was well under way. It was accompanied by the resignation of several prominent members and "to stop controversy, Mussolini became Minister for Army, Navy, and for Air. 4" The year was also marked by the transfer of aeronautical functions, personnel, installations, and equipment from the Army and Navy to the Air Force. The gradual clarification of organizational, administrative, and functional problems of the new arm continued into the next year. The number of operational squadrons of the Air Force was increased to 66 by November 1924, while aeronautical firms submitted for consideration 15 new experimental aircraft and 4 new types of engines. A year later the Air Force had been increased to 90 squadrons and the bureaucratic reorganization of the Air Ministry was completed, thus putting it operationally on the same basis as the Army and Navy.

3. Jane's All the World's Aircraft for 1923, 1924, 1926.
By 1925 the aeronautical program of Fascist Italy was established and its intent was clear: (1) Prestige through augmented strength of the Air Force, (2) Development of civil aviation and extension of air lines, (3) A strong and sound aeronautical industry which could bid successfully in foreign markets for aeronautical equipment. National prestige has never been a very conscious factor in American thinking; consequently it is easy to discount its importance in the eyes of a nation whose prestige is not great or has suffered a decline. Practically, its consequences are felt in international bargaining for commercial and other considerations. The thwarting of Italy's hopes for territorial aggrandizement as a consequence of her participation in World War I was a national humiliation. Restrictions upon her exports of her products and her surplus population as well as upon her free access to important raw materials, were disadvantages keenly felt by the Italian people. The Fascist government, in its efforts to build up an international prestige, sought to make the nation militarily strong, economically self-sufficient, and to rise no opportunity for the development of a profitable foreign trade. The reorganization of the air reflected all these aims. The rapid equipping of some 90 air squadrons markedly enhanced Italy's relative military strength with respect to other countries. The development of civil aeronautics and the extension of Italian operated airlines increased the nation's prestige while at the same time it provided a certain economic support for the expansion of the aircraft industry which was of even greater military-political significance. The advanced state of Italian military and civil aeronautics, it was expected, would create a demand for Italian aircraft in foreign countries; thus providing further economic support for Italy's essential aircraft industry, while at the same time the export of Italian aircraft would contribute to the growth of prestige and provide foreign exchange which could be used to provide essential raw materials for the aeronautical and other industries as well. The widespread consciousness of the importance of prestige among the Italians was reflected in the formal establishment of propaganda agencies in its major civil and military organizations.

In the fulfillment of this program, aircraft manufacturers, encouraged and aided by the government, developed aircraft for international competitions and the capturing of various kinds of international records—speed, altitude, endurance. In Italy, as elsewhere, these exploits contributed to the development of popular pride in the achievements of Italian aeronautics and consequently support for the expensive government development of military and civil aeronautics.

5. In 1929 Coma, Francesco de Agostini flew from once to Japan and returned by way of Siberia, Australia—a distance of 28,000 miles; in 1929 the Amundsen-Scott-Forsyth-Smith expedition employed a semi-flight Italian-built airship, the "Herm", in a flight over the North Pole from PRIMUS Bay, Spitsbergen to Reykjavik; Asia—a distance of 2,700 miles; in 1929 Coma, Francesco de Agostini's "continental flights—Antarctic, 50,000 miles; North America, New Zealand, Africa; "terrestrial" flights in the popular mind by the flights of "Andes, "Nembuti", and "Dakar"; the same year in 1927 the "N" "N" actually established the new plane record of 2,578.95 mph; in 1929 Count Augusto Ferreris and Maj. Carlo A. Belpas made a non-stop flight from Fortaleza—Brazil—a distance of 4,456 miles.
During the late 1920’s and early 1930’s the government depended heavily upon the personal and physical resources of the aeronautical industry to accomplish its ends. This was the product both of necessity and of design. The industry was absolutely dependent upon government contracts and support if it was to flourish or even if it was to exist. Concurrently, research and development was carried on largely in industrial and university laboratories, the function of the government experimental establishments (with the exception of the one establishment for the construction of airships and kite balloons at Ciampino) being that of service testing of equipment and models that had been developed elsewhere.

A factor favoring the development of Italian aviation during the 1920’s involved availability of raw materials. The aircraft of this period were still substantially constructed of wood and fabric, and Italy had a sufficiency of wood for airplane manufacture and an abundance of craftsmen skilled in woodworking. Castor oil, which Italy produced in abundance, was still regarded as a satisfactory lubricant.

Military contracts were distributed to the different aircraft and engine manufacturers. 6 New aircraft and engines were developed by industrial laboratories with the active cooperation and collaboration of military engineers who were often, at the same time, professors of engineering and aeronautical science at the universities. Experimental aircraft and engines, produced by industry, were tested at governmental experimental centers with a view to determining whether they would be cut into production for military use, held from production for further development, produced for civil aircraft, or released for sale to foreign purchasers. Prizes, direct and indirect subsidization, and government contracts were the means by which new development was fostered. However, no manufacturer might count upon exclusive production rights to a particular type aircraft or engine since the government distributed its contracts with a view to maintaining and enlarging the general productive capacity. 7 To this end, Italian practice differed from that of other countries with respect to maintenance and repair. This work was performed for the Air Ministry by the manufacturers. 8

The government fostered the development of air lines by direct subsidization through outright grants, maintenance subsidies which were standardized at a sum equivalent to one-half of the cost of air miles flown. Indirect subsidization of both civil and military aviation was given through the assumption of general expenses by the government which included such items as pay of civil personnel of central administration, telegrams, legal expenses, subsidies to civil and military personnel, premiums for studies and inventions, expenses for military aeronautical propaganda, statistical work, and confidential expenses. 9 The Air Ministry paid funds to civilian pilot training centers for the complete training of a flier, for partial training, and for refresher training of reserve fliers. 10

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7. Ibid., and Military Attaché Reports.
8. Ibid.
9. Ibid.
10. Ibid.
However, the importance of basic scientific research had been clearly recognized by the government which, from the beginning, was confronted by the country's lack of raw materials essential to her manufactures. A solution to this difficulty was sought through the laboratory, and during the first decade of Fascism a broad program of research was vigorously advanced by the government with important consequences in agriculture and industry. It was but natural that this general program would encompass aeronautical research and that in the fulfillment of a general policy with respect to basic research the government would establish the needed facilities and controls. This was accomplished during the years 1930-1936.

In 1936 the aeronautics industry was authorized to spend 30 million lire over a period of four years for "the necessary work in connection with the organization of a center of studies, tests, and aeronautical construction at Montecelio." Montecelio was the experimental field of the Aeronautics outside Rome, but in 1930 it was rather primitive and possessed little equipment for experimental work. The expansion of the experimental center at Montecelio, renamed the 3 Idoias Experimental Center, dominated the history of Italian aeronautical research and development during the next decade.

The date of the establishment of this experimental center probably has some significance. During the first period of the expansion of Italian aeronautics under Fascist auspices, Italy was not nearly so seriously handicapped in the matter of raw materials as she was later. In the late 1920's there was a noticeable trend among newer types of aircraft toward the more extensive use of metal in construction. Perhaps it should also be noted that the relative ease with which Italy had established herself as one of the foremost air powers was in some degree due to the fact that the construction of her air force had taken place during a period of relative world peace when armament competition among the nations was being de-emphasized. At any rate, the 3 Idoias Experimental Center had achieved impressive numerical strength. The problem which lay ahead was to see the nation abreast or ahead of the rest of the world in new developments. As the Fascist government entered its second decade, it was apparent that Italy's position as an important air power would become increasingly difficult to maintain as other industrial nations entered the competition and as more modern aircraft increasingly employed materials which Italy could not provide.

The construction of the Idoias Experimental Center at Montecelio extended over a period of approximately six years. The work actually began

13. The progress of the Guidonia experimental center may be followed in "Military" image reports, in the reports of the MICA Technical Assistant in Europe, and in items published in Inter-Avia, a Geneva news letter devoted to aeronautics which was published three times a week, as well as in a series of articles appearing in technical and aeronautical journals.
in 1929 when steps were taken to construct a wind-tunnel at Montecchio, it was accelerated the following year when an appropriation of 30,000,000 lire for development was authorized, and continued into 1936. After an inspection in October 1936 the American Military Attaché reported that "The R. Aeronautes Experimental Center is the Italian equivalent of the N.A.C.A. Laboratories and Wright Field combined. Theoretical and practical experiments as well as flight tests of new land planes are carried on at this station." He estimated that some 50 million lire had been expended on construction and installations. Earlier in the year NACA representative reported: "The equipment here comprises a towing-basin 1,650 feet long with possible extensions to 2,600 feet; identical single-return tunnels for routine tests with twitches 6.6 feet in diameter, and speeds of 157 miles per hour; a 10-foot double-return tunnel with a speed of 242 miles per hour, thanks to the 1,800 horsepower motor; and a ten-foot vertical tunnel for spinning tests." In December 1936 he supplied further description of the progress that had been made: "a 13-stage, 2,500 horsepower, 3-atmosphere supersonic tunnel has been completed at Guidonia, in which a speed of more than twice that of sound has been reached, together with temperature of -990 C. and pressure equivalent to that at 75,000 feet."  

This last fact is of special significance, for it was in the study of supersonic speeds and stratospheric flight that Italian research gained the advantages of initiative. In an introduction to a published interview with Sig. Crocicco in August 1934, the editors of Inter Avia noted: "The scientific and technical development in this respect, Italy has created a technical department for stratospheric research, known as the Rampa d'Alto Reide and the cooperation of the most eminent scientists and authorities of Italy." At the same time a high-speed school maintained by the government at Lake Garda enabled Italy to retain the world speed record for several years.  

It was noted that this specialization in high speed flying "produced practical results in improved streamlining, control at high speeds, engine cooling, and high altitude performance," and that the experimental and research program "has been thoughtfully coordinated in the magnificent new air city of Guidonia," where the government has assembled a corps of scientists, each qualified in some special form of aeronautical research. But in the same report it is noted that in the war in Ethiopia (1935-36), Italian equipment was inferior. The long distances to be traversed forced Italian planes to fly low with heavy fuel loads. In mountainous country...

16. C-2 Report L. 15594, 27 October 1936, Italy. See also reports A12268 and A114099.
17. Aircraft Year Book, 1936.
the low ceilings of the planes and the serious handicap that the "\textellipsis" equipment did not send its best aircraft to Abyssinia, it is also a fact that the air force built up during the 1920's had become obsolete and that equipment had not been replaced.

In 1934, the Air Force announced that 120,000,000 lire would be spent during the course of the next five years for renewing old and obsolete aircraft. Late in the year the military attacks in Abyssinia, the policy of building principally experimental prototypes, which was followed up to the present, will terminate in the near future. The period of replacement of old and obsolete aircraft in the 120 squadrons existing in Italy will begin soon. Is further reported that about 30 squadrons of the Air Aeronautics were equipped with obsolete or obsolescent types. The planes were equipped with superchargers—an interesting fact considering the theoretical and experimental interest in high altitude flight, less than ten percent of the service type had metal propellers, and no planes in service were equipped with variable pitch propellers. Furthermore, Italy had continued to manufacture planes of wood and fabric construction despite the almost universal adoption of all-metal construction. The American Military Air Force visited the most important aircraft factories with a view to ascertaining the reasons for the limited use of metal. This was attributed to the lower cost of wood-fabric construction, the abundance of craftsmen for wood-fabric work and the possibilities of rapid expansion, the availability of materials in Italy which obviated the necessity of making purchases abroad as well as the danger of being cut off from essential materials in the event of war. Electric welding of aluminum had not yet been attempted by Italian aircraft manufacturers, and with a single exception all work with stainless steel and Bond process of welding had been discontinued. This was attributed to the necessity of importing steel, the cost, and the difficulty of obtaining trained workers.

The same considerations resulted in the determination to use motor oil for the lubrication of both aviation and automobile engines. And the same necessities determined the persistent efforts of Italian scientists to perfect the "gasogine" engine which burned a fuel manufactured from an indigenous shrub.

Impressive as was the set-up at Quindina, the sum of money spent on its development, and the coordination of the research facilities and personnel of industry, the universities, and the military service, it was unable to solve many of its basic problems rapidly enough to meet the demands for the expansion of the nation's military forces.

17: Ibid.
20: O-2 Report L. 4409, 1 November 1934.
21: Ibid.
23: Ibid.
25: It should be noted that this breakdown is highly superficial, for the same individual often occupied a prominent place in two or all of these categories. G. L. Croce, a prominent member of the R. Acad. d'Italia, was a Lieutenant General in the Royal Corps of Engineers and Professor of General Aeronautics at the University of Rome.
Before the launching of the Abyssinian campaign, Berlin and Paris had allowed Mussolini to think that England and France would stand aside and regard the conquest as compensation for Italy's failure to receive important territorial concessions at the close of World War I. The violent popular reaction to the great act of aggression, particularly in England, took the Fascist by surprise. Italian reaction toward the Abyssinian war was at the outset either favorable or indifferent. To intensify the situation, which was critical for the government, the Italian air force was moved up to a high pitch of chauvinism by a violent propaganda of domestic origin, and the air superiority of Italy's military force was undertaken. Italian air power was built up as a counter threat to British sea power in the Mediterranean. The point is that Italy was forced to expend her air power before her program of research and development had been perfected.

In June 1935, the German technical advisor of the Italian recorded: "A great air force has been built up by Italy in a remarkably short time and at a relatively moderate cost due to the widespread use of rolled-steel tubes for the fuselage members and wood fittings. Special emphasis has been placed on the production of bombers, aircraft which present a great threat to the British Mediterranean Fleet at the period of extreme tension between Italy and France. Bombing aircrafts are usually intended for use in military incursions, and by accumulating good records with specially built aircrafts, Italy created an illusion of operational reach. The belief that French public opinion was much stirred by the knowledge of records which Italy had by way of existing French airplanes in respective categories. As such, this strengthened the temporarily position of the Axis, but on the part of Italy it seems to have been largely a successful bluff.

The rapid march of events which eventually embroiled the nations of Europe in World War II placed a strain on Italian resources—military, economic, and financial—on which the Fascist regime, quite early, had placed a strain on the country. The Abyssinian campaign led to in 1936 was followed in July by the French Rebellion in Spain, and a few months later, which was not concluded until the spring of 1939. This campaign was assisted by the construction of formidable airfields and other bases in Spain by the Fascists. The Italian consulate in Italy, 1939, while not an extensive or costly enterprise, was an additional tax in limited resources.

Italy's economic weakness forced Mussolini to play a game of bluff in converting the more powerful European states. His tactics from the start were to take advantage of the state of unpreparedness of the non-Fascist nations, to exacerbate Italy's state of preparedness, and to emphasize the importance of the Italian forces that could be instituted through air power.


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on an unprepared nation. Early in the 1930's he remarked: "In order to be humanitarian a war must be concluded rapidly, the maximum effort with all available means must be produced in the shortest possible time." To appreciate the significance of this statement, one should substitute for the humanitarian factor, Italy's economic weakness. 29

"As Europe approached World War II, the weakness of Italy's position became more and more clear. In 1937 it was noted: "As in other totalitarian states the national economy of Italy is directed toward self-sufficiency and preparedness. Italy is lacking in material resources and her population is so predominantly agricultural that her drive toward self-sufficiency have been realized only in relatively small degree." No amount of "double-talk" was able to obscure these facts. In March 1940, General Prisolo, Undersecretary of State for Air, presented the Air Budget for the following fiscal year. In doing so he discussed the production rates of various countries, during the course of which it became clear that Italy's expanded production capacity "would be inferior to that of other countries."

To overcome this factor, it was made apparent that the government intended to pursue its established policy of producing quantities of aircraft in advance of other nations so that in the event of war the Italian air force might get in "instant with the mostest." Prisolo asked: "Is it better to have a very reliable plane in the units, of surpassed characteristics, or a machine of higher characteristics which may present some disadvantages?" He supplied the answer to his rhetorical question: "We are convinced of the necessity of working toward standardization of material, that is, of reducing to a minimum the number of standard planes, engines, arms, equipment." Later on he added: "The potentiality of aeronautical construction naturally depends upon the availability of raw materials. Without going into details I can affirm that the Air Ministry and industry obey the order to use national raw materials, for we are convinced that though this is sometimes more costly, it is nonetheless to the interest of the nation." The Military Attaché noted: "As far as facilities are concerned the industry is capable of considerable expansion. The procurement of essential materials, tools, skilled personnel, however, rather than the question of facilities, will govern the potential output of industry." 30

Needless to say, the performance of the more advanced types of Italian aircraft were of considerable interest to foreign powers. In planning a revision of the five-year experimental program for the U. S. Air Corps, the Air Board, in comparing characteristics of foreign aircraft with American military planes noted the superior speed of the Piaggio P-10 in over other comparable heavy bombardment aircraft like the Sunderland Flying Boat and the

29. 9-2 Report.
31. 9-2 Report No. 17, 431, 18 March 1940.
32. Ibid.
33. Ibid.
Junkers Ju 89. Very significant, however, was the fact that whereas the latter two craft were in production, the threat of the Italian plane was reduced by "12 aircraft on order." 34

During the years preceding World War II, the junior Axis partner found himself in the ridiculous position of a small bully boasting of his strength and threatening bigger boys who opposed him with reprisals by his big brother. However, since the combined strength of the two Axis brothers, or partners, was formidable, the stuff met with considerable success.

The test of war revealed the weakness of Italian aeronautics. This in turn reflected the inability of Italian research to overcome the disadvantages resulting from a critical shortage of materials. The picture is reflected in an operations analysis report on the Italian Aircraft Industry made in April 1943. 35 The report states that the Italian aircraft industry, unlike the German industry, does not present a primary objective for Allied air attack. "The record of the Italian Air Force in the present war is not impressive, in general, neither the quantity nor the quality of its operations has been high. The major causes of weakness have been: (a) low production, and lack of reserves; (b) failure to develop and put into mass production new models comparable in performance to latest Allied models; and (c) poor training." 36

It was noted that "prior to her entry into the present war, Italy relied heavily upon imports of many vital materials, parts, and machinery to sustain aircraft production. The continued inflow of these items since 1939 has depended largely upon German choice in the matter." 37 It is apparent that the Germans initially considered using Italian production facilities to build up the strength of both Axis air forces by exchanging technical information, supplying necessary raw materials and machinery, sending German technicians into Italian plants, introducing German models, and in general coordinating the industrial production of Italy and Germany. 38 However, due to financial difficulties Italy has been unable to put her aircraft industry underground. The industrial population of Piedmont and Lombardy has given evidence of having tired of fascism and their resentment of German overlordship was acute. It was eventually decided to transfer Italian labor to Germany to work in German industry.

36. Ibid.
37. Ibid.
38. Ibid. See also 3-2 Report 17.114, 30 June 1939, and Collaborazione Scientifica Tecnica Italiano-Germanica, relazioni sulle missioni in Germania, August 1942, in 3-2 Library, Italy 9545 Encl. File 17 November 1942, D93559, which, despite its tactful wording is a confession that at this date the Germans were primarily interested in extracting information upon the aerodynamics of wings at supersonic velocities and data upon the behavior of bombs in water, fields in which the technicians of Caudron had obtained more experience and better results than the Germans.
39. 3-2 Report 17.114, 30 June 1939.
It is pointless to attempt to appraise aeronautical research in Italy in general terms of success or failure. But it is useful to note what it attempted and what it achieved in terms of the conditions which were confronted. It is well to remember that Italian aeronautical research formed part of a comprehensive (or totalitarian) research program begun as early as 1921 with the setting up of a National Research Council, and that the practical application of its efforts was limited by the objectives of the national research program. Effectively this meant that it sought to make the maximum use of national material resources and to avoid pushing developments which would foster a dependence upon foreign sources. Along with this was the requirement to produce experimental aircraft for show—that is, to uphold Italian prestige in international competitions. Such a program, pursued in an era of peace, might have resulted in the production of low-cost aircraft of high performance. However, the international policy adopted by the Duce demanded a large air force. Italian aeronautical research was unable to create superior aircraft and means of production from available material resources. Perhaps it attempted what was impossible.

In one particular, Italian experiment and research produced a weapon which was unique and which gave the Axis an advantage over its enemies. That was the jet-propelled plane, a weapon which was perfected and employed by the Germans. Its development covered more than a decade. The idea was not new. It had been conceived and illustrated by Emilio Lorus in 1913. The theoretical and mathematical work had been carried on by G. S. Steckin during 1924. The Italian engineer J. Campini, creator of the CC-1 and CC-2, recorded the first fruits of work done in 1922 in an article published in the Rivista aeronautica in 1930. Gen. Prof. Crocco drew attention to the work being done on jet-propulsion in a paper presented to the R. Accademia Nazionale dei Lincei, and a technical discussion of the motor and forces, with a mathematical analysis of its working principles, was published in Aeronautica in January 1932.

In an interview published in Inter-Avia in August 1934, General Crocco was asked, "Has your work also included rocket-driven aeroplanes?" "Yes," he replied, "and it may be said that I am one of the pioneers in this anticipation of mechanics which is now interesting experts more and more. By means of aircraft actuated by rockets, it is hoped that results far in excess of those made possible by the actual engine-and-aircrew combination may be attained, and that even the fascinating limit presented by the velocity of sound may be surpassed. A new theory of aerodynamics is in course of formation, based on the study of atmospheric resistance beyond this mark; and this study of ultra-sonic velocities has only been approached, as yet, by certain calculations of artillery."

42. "Caratteristiche e possibilità della propulsione a reazione", Part I, in Rivista l'Aeronautica n. 8, Anno 10, Part II, in n. 10, Anno 12.
43. Ing. Ugo de Caria, "I Termo - Propulsori a reazione" in Aeronautica, January 1932.
44. Inter-Avia, No. 143, 23 August 1934. In AAF Library.
In the bibliography appended to his article cited above, Campini lists several articles by Crocco and three NACA Technical Notes including one covering a test on thrust augmentors for jet propulsion, which seems to indicate that American aeronautical scientists were not neglecting the possibilities of jet propulsion.\textsuperscript{45}

Campini, working as an Aeronautical Engineer at the Caproni plant, perfected his first model in 1939. The machine was inspected by General Prisco, Undersecretary of State for Air, in January 1940\textsuperscript{46} and the first flight was made with the new plane, the Caproni-Campini-1, on 27 August 1940.\textsuperscript{47} The first model took off using a propeller and then switched to jet propulsion. The test flight was apparently not repeated, but on 1 December 1940 the CC-2, a heavier plane without a propeller, made a test flight from Milan to Rome, piloted by Capt. Mario de Bernardi, the Italian Schneider Trophy pilot.\textsuperscript{48} On the occasion of this second flight, the pilot, Capt. de Bernardi, suggested that the speed of the conventional airscrew-propelled aeroplane was reaching its upper limit and that still faster speeds could be obtained only by fundamentally new design, of which the Caproni-Campini aeroplane was one example.\textsuperscript{49}

In view of the poor performance of the Italian air force in the war, the tendency of American journalists was to scoff at Italy's claim, or at least to scoff at the implication that a new weapon had been developed. Amazingly enough, on 23 December 1940 there appeared in the New York Times, side by side, two items dealing with what were then referred to as "rocket" planes. One "pooh-poohed" the Italian announcement by stating that engineers agreed that the principle (of a rocket or jet-propelled plane) could not possibly be of any aid in the present war. The other was a follow-up to a news item of 11 December which was headed "Air Supremacy Seen in New 'Rocket' Motor That 'Could Add Greatly to Planes' Speed."\textsuperscript{50} This dealt with the announcement by the Daniel Guggenheim School of Aeronautics of New York University, that E. B. Myer had perfected a jet motor to assist in airplane take-off, after four years of development.

Interest in the possibilities of jet-propulsion seems to have been fairly universal. In his column "Air Currents" just cited, Frederick Graham noted that the Germans were currently experimenting with jet and rocket aids to the take-off of heavily laden craft but, like the American E. B. Myer, they had encountered difficulty in obtaining a metal sufficiently resistant to the intense heat engendered to permit of continuous operation for more than a brief interval.\textsuperscript{51} It has seemed to have received continuous encouragement as a result of the fact that Sig. Crocco, a Lt. General

\textsuperscript{46} Inter Avia, No. 694-695, 30 January 1940. Incidentally, the firm Caproni Aircraft in France, obtained a patent for a jet-propelled plane in 1932; see Willy Ley, "Experiments in Jet Propulsion" in Western Flying, December 1943, p. 49.
\textsuperscript{47} Inter Avia, No. 733, 28 October 1940.
\textsuperscript{48} Willy Ley, "Experiments in Jet Propulsion," in Western Flying, December 1943, pp. 48-49, 100.
\textsuperscript{49} "Jet Propulsion In Italy" in The Aeroplane, London, Vol. LVI, No. 1596, 26 December 1941, p. 697. AAF Library.
\textsuperscript{51} Ibid.
in the R. Corps of Engineers, a professor at the University of Rome, and a prominent member of the R. Accademia, was himself interested in the problem and continually drew attention to the experimental progress being made in this field.

In reviewing Italian aeronautical experiment and development, one is struck by the fundamental sameness of the problems as they are confronted in a totalitarian state and as they are confronted in a democratic state. Where the Italians seem to have failed is in the field of production. They have consistently exhibited in the field of aeronautics, and in other fields as well, a peculiar lack of interest in the effective embodiment of the latest scientific experience in the techniques of production. The nation is still essentially made up of agricultural workers and an industrial population who are craftsmen at heart, and the attitudes characteristic of these groups are reflected in the thinking of all classes. National vanity is frequently satisfied by a gesture—like the winning of a speed record, a spectacular world flight like the Balbo expedition to the Chicago World’s Fair, or a numerical increase in the armed forces in a tense international situation.

In perusing the reports on scientific developments, and the utterances of military personnel—even in the presentation of budgets to the Chamber of Deputies—one is struck by their academic character. On the technical side, the Air Ministry and the R. Aeronautica seem to have been saddled with too many professors whose interest was mainly in the theoretical and experimental nature of aeronautical problems and whose interest in the practical problem of production was purely academic. This may merely reflect the fact that in this latter field they were severely restricted by the overall requirement to avoid the use of materials which were not produced locally. It was an important restriction.
Comparative Statistics on Italy's Aeronautical Industry

The statistics appended cover (1) the Italian aeronautical budget, prospective and actual, expressed in both lire and dollars, from 1923 to 1941, and (2) subsidies to aeronautics in England, France, Italy, and Japan, from 1922 to 1933, when figures are available. The value of such figures is very approximate. For example, to arrive at a true estimate of comparative subsidization, one would have to take account of living standards in the various nations concerned from year to year and the actual purchasing power within each state in terms of labor and materials. Obviously the international exchange value of Japanese yen gives slight indication of the value of the labor that may be purchased by official currency within Japan. After 1933, the published figures on expenditures for the support of aeronautics by subsidization or other means, were frankly deceptive. Consequently, the total budget for aeronautics in Italy is considered a more useful index of the situation than any set of figures that could be obtained representing subsidization.
L.I.T.'s PROFESSIONAL BUDGET, 1923-1943

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<th>Actual Expenditures</th>
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<td>Lire</td>
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<td>1939</td>
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<td>1941</td>
<td>7,267,678,000</td>
<td>333,379,670</td>
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From 8-2 52, at 17,572, 9 July 1942, Military Attaché, Rome, Italy.
### Indirect Subsidies to the Aviation Industry (for military aviation), 1922-1933

<table>
<thead>
<tr>
<th>Year</th>
<th>England</th>
<th>France</th>
<th>Italy</th>
<th>Japan</th>
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<td>1922</td>
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<td>95,734,342.</td>
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<td>1927</td>
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<td>43,786,283.</td>
<td>129,332,700.</td>
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</tr>
<tr>
<td>1928</td>
<td>73,307,252.36</td>
<td>43,786,283.</td>
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<td>1929</td>
<td>33,576,366.</td>
<td>74,911,900.</td>
<td>137,290,060.</td>
<td>35,616,480.</td>
</tr>
<tr>
<td>1930</td>
<td>34,201,000.</td>
<td>50,549,110.</td>
<td>133,527,127.33</td>
<td>23,525,306.68</td>
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<td>1931</td>
<td>32,766,420.</td>
<td>79,340,297.</td>
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<tr>
<td>Year</td>
<td>England</td>
<td>France</td>
<td>Italy</td>
<td>Japan</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
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</tr>
<tr>
<td>1924</td>
<td>1,041,179</td>
<td></td>
<td></td>
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<tr>
<td>1925</td>
<td>996,361</td>
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</tr>
<tr>
<td>1926</td>
<td>1,009,555</td>
<td></td>
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<tr>
<td>1927</td>
<td>994,755</td>
<td>17,926,615</td>
<td>1,563,570</td>
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<td>523,331</td>
<td>19,933,000</td>
<td>6,715,000</td>
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<td>735,165</td>
<td>22,070,197</td>
<td>7,657,700</td>
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<td>1930</td>
<td>183,657</td>
<td>6,000,000</td>
<td>670,973</td>
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<tr>
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<td>676,827</td>
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<td>147,130</td>
<td>2,092,700</td>
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<tr>
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<td>761,227</td>
<td>922,247</td>
<td>152,133</td>
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</tr>
<tr>
<td>Year</td>
<td>Restored</td>
<td>France</td>
<td>Italy</td>
<td>Japan</td>
</tr>
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<td>------</td>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>1926</td>
<td>3,706,103</td>
<td>13,513,000</td>
<td>4,399,125</td>
<td></td>
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<td>1927</td>
<td>4,325,437</td>
<td>14,943,000</td>
<td>4,825,000</td>
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<td>5,050,116</td>
<td>15,391,000</td>
<td>5,017,000</td>
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<tr>
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<td>5,556,432</td>
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<td></td>
<td>3,173,120</td>
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<td>16,776,000</td>
<td>5,219,240</td>
<td>2,063,139</td>
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<tr>
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<td>8,027,400</td>
<td>18,413,140</td>
<td>5,853,000</td>
<td>1,953,150</td>
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<tr>
<td>1932</td>
<td>9,227,600</td>
<td>20,123,753</td>
<td>6,931,120</td>
<td>1,537,120</td>
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<tr>
<td>1933</td>
<td>10,427,800</td>
<td>21,933,125</td>
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</tbody>
</table>
### Miscellaneous Aids to Aviation, 1923-1933

(Flying Clubs, Private Touring Aviation, Training Civilian Pilots, etc.)

<table>
<thead>
<tr>
<th>Year</th>
<th>England</th>
<th>France</th>
<th>Italy</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923</td>
<td></td>
<td></td>
<td></td>
<td>132,132</td>
</tr>
<tr>
<td>1929</td>
<td></td>
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<td></td>
<td>174,332</td>
</tr>
<tr>
<td>1930</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1931</td>
<td>33,091.42</td>
<td>150,000</td>
<td></td>
<td>33,220.13</td>
</tr>
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<td>1932</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td></td>
<td></td>
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</tbody>
</table>
Part C

SCIENTIFIC DEVELOPMENT IN FRANCE, 1914-1945

Since the time of Descartes, scientific investigation has had a great attraction for the French mind. In the days of the monarchy and the Napoleonic empire, the state subsidized and controlled most scientific research, but during the nineteenth century government appropriations tended to be uncertain and irregular, and the advancement of science was more dependent on the efforts of the savants themselves, or the generosity of wealthy patrons. The official indifference, even hostility, which handicapped the work of scientists like Cuvier and the Curie was not unusual during the Third Republic, although since 1900 most governments have tried to do better by French science.

Elsewhere, the universities and technical schools have been centers of scientific investigation. Four bodies in particular have led the way in scientific endeavors: they are (1) the Academy of Sciences, (2) the science faculty at the École Polytechnique, and (3) the École Normale Supérieure. In Ireland, there has been a tendency for those great institutions to deal more with theory than with the practical application of new ideas, and for some time the French government made little effort to bridge the gap between research and those most anxious or able to utilize it. There was also a tendency for these honored and venerable academic corporations to consider themselves "oasis shops", and to regard with some initial distrust, the ideas of outsiders.

However, after the First World War, the government has established many new organizations to further scientific research, although it has not always shown a disposition to supply them very generously with funds. In 1922 was founded the National Office of Scientific and Industrial Research and Inventions (Office National des Recherches Scientifiques et Industrielles et des Inventions) to foster research needed by the public services and to coordinate public and private investigations. In 1922 it was proposed to devote a regular income to scientific studies, and one seventh of a new tax on industry was allocated for research purposes. In 1925 as much as 5,000,000 francs was so provided, but the following year the amount was decreased, and similar reductions continued into the thirties. On one occasion when Herriot proposed a credit of 20,000,000 francs for scientific purposes, the Chamber only voted 5,000,000.

1. Prepared by Dr. John F. Barkey, WINS, April 1945.
3. Ibid.
5. Ibid.
When the Higher Research Council (Conseil Supérieur des Recherches) came into being in 1933 with sections corresponding to the several sciences, and representatives from other interested and associated fields, considerable efforts were made to obtain more adequate funds from the government. Madame Curie lent her famous name to this activity, and a measure of success was achieved. In 1935 a total of 15,500,000 francs was realized, and when the Blum ministry came into power the next year, an under-Secretary of State for Scientific Research was created. The ever-growing threat of war apparently bestrided the Chamber into a more serious consideration of the needs of French science, and in 1937 26,000,000 francs was voted for research purposes. In the 1939 budget this sum was increased to 12,000,000 francs.

In 1936 the Central Service for Scientific Research (Service Central de la Recherche Scientifique) came into being, and two years later the National Center of Practical Research (Centre National de la Recherche Scientifique Appliquée) was established. Both organizations were coordinated by a committee in the Ministry of Education. The Central Service consisted of the astrophysics service, the large-scale chemical laboratory, the atomic synthesis laboratory and the Institute for Textual History. The National Center contained some twenty sections, representing all the major fields of modern science. The members of the Center were chosen from (1) scientific workers, (2) representatives of industry, agriculture and commerce, as well as the state departments, and (3) representatives of defense groups. In July of 1933 an Institute of Scientific Research for National Defense was founded to study scientific problems which might aid the country in wartime. The Institute was a cumbersome body of 46 members, and was top-heavy with important and busy people. Its membership included the premier, cabinet ministers, scientists, and high-ranking representatives of army, navy and air. Obviously, not much intensive work could be expected from such a body, and not much was accomplished.

From this brief sketch, some idea of the organization of research in France can be gained. As with England, the progress of French aviation was to a great extent determined by the conditions affecting scientific investigation in general. As one might expect, the earliest aeronautical experiments in France were conducted by air-minded enthusiasts financed by private individuals. Governmental patronage was to come only after the airplane had established itself. However, this original lack of official appreciation does not seem to have greatly hindered early aviation in France. Indeed, its achievements were great. Its planes were, on the whole, safer and more stable than the early Wright machines, and many fundamental inventions such as the monoplane, the fuselage, landing wheels, ailerons and control by means of the "stick" are French achievements.

In 1909 Eiffel established the famous laboratory for aeronautical research bearing his name. He furnished the money, and directed the research himself with the assistance of a small staff. The laboratory equipment

6. Ibid.
7. Ibid.
3. Ibid.
was mainly a wind tunnel and consequently the field of experimentation was somewhat limited. About the same time that the Eiffel Laboratory was created, Henri Deutsch de la Meurthe founded the Aeronautical Institute at St. Cyr with a grant of 211,000 and a promise of 10,000 per year for maintenance during his lifetime. The Institute was placed under the technical direction of Prof. Louis, a distinguished scientist at the University of Paris. A large body of eminent scientists acted in an advisory capacity. The scope of the work of the St. Cyr Institute was virtually unrestricted. Mention should also be made of the balloon laboratory at Chalais-Meudon which had functioned since 1907. However, this institution did not undertake experiments with heavier-than-aircraft until sometime later.

In 1909, the Ministry of War created a small military aviation establishment and attached it to the artillery. At the 1910 maneuvers the use of planes in reconnaissance and in fire control created something of a sensation, and henceforth their use by French military organizations was assured. By the outbreak of the war, France had spent more on aeronautical research than any other country except Germany. In 1912 a Directorate of Military Aviation was organized in the War Ministry and in 1913 it took over the laboratory at Chalais-Meudon which was transformed into a laboratory for aeronautics and also served as a center for aviation material.

The war brought about a tremendous expansion of French aircraft, and by the signing of the armistice, France was probably the first air power in the world. The Under-Secretariat for Air in the War Ministry which had been set up in 1917 was abolished in the year following the war, and from 1920 to 1926, the air force was split up among the Ministries of War, Marine, and Colonies; these fragments were coordinated by an Under-Secretary for Aeronautics and Air Transport established in the Aeronautical Section of the Ministry of Public Works. Scientific and technical organizations were placed in a number of Divisions (Services). The Division of Aeronautics (Service Technique de l'Aeronautique) contained sections on hydro-navigation, ballooning, motors, fuels, aerial navigation and armament. The Research and Experience Division (Service des Recherches et Experiences) pronounced on the value of inventions submitted to it, and tried to coordinate research in the different divisions, and manage certain laboratories. The Division of Studies (Service des Etudes) established construction programs involving new equipment and inventions, while the Division of Tests (Service des essais) made actual test flights with prototypes.

In spite of these elaborate organizations, French aviation in the twenties began to lose something of its quantitative and qualitative superiority. In the opinion of some French writers, this was due to the lack of a better technical direction, and the lack of scientific advances in the industry itself. Writing in 1924, Captain Rene Fonck, a former war ace, stated that

11. Ibid.
12. Annuaire de l'Aeronautique, 1926
...an effective technical direction, and a unified metallurgical development are the two fundamental needs which both the military and commercial aviation have in common. ... We would be much farther ahead if there were more method in our work, if we had comprehended the fundamental relationships between the various branches of aeronautics.\[13\]

He concluded by calling for amalgamation of scientists, specialists, inventors, and skilled workmen to aid the aircraft industry.

Some years later, Pierre Etienne, a writer of some repute on aeronautics for various technical periodicals, expressed the opinion that as early as 1926 France was beginning to lose out in the struggle for air supremacy, and that this decline could be attributed to a lack of appreciation for, and information on certain technical advances. "This decline can be expressed in this way: our builders were still working to perfect pursuit planes with a speed of 300 kilometres per hour when there were actually in service British planes that could surpass this speed by 40 kilometres." \[14\]

In 1926, the Under-Secretary was abolished and its powers transferred to a directorate of Aeronautics and Air Transport (Direction Generale de l'Aeronautique et des Transports Aeriens) attached to the Ministry of Commerce and Industry. The Technical Division was joined with a production organisation known as the Division of Manufactures (Service des Fabrications) and was renamed the technical and industrial division (Service Technique et Industrielle). Thus to questions of research and prototypes were now joined problems of control of manufacture and raw materials.\[15\]

The new directorate came to an end in 1927 when an Air Ministry was established. The following year the Technical and Industrial Division was reorganized and renamed the Technical Directorate (Direction Generale Technique). Its purpose, in the words of the directive was to "direct... the research and to the improvement and development of aeronautical equipment."\[16\]

Its four principal divisions covered (1) research, (2) technical developments, (3) aircraft manufacturing, and (4) supervision of air bases. Along with these four bureaux, there was an advisory body known as the High Council of Scientific Research (Conseil Superieur des Recherches Scientifiques) consisting of leading figures in French science and presided over by the Air Minister himself.

Through a reorganization in 1931, the Technical Directorate became the Technical and Industrial Division and Air Navigation Service (Service Technique et Industriel et Service de la Navigation Aérienne) and was divided into divisions controlling research, technical development, manufacture, and air bases. The first two were entrusted with scientific studies. The

16. Annuelles de l'Aeronautique, 1929
17. Ibid.
Division of Research was divided up into sections concerned with aerodynamics, raw materials, and machines while the Technical Division's sections dealt with planes, hydroplanes, motors, equipment, armaments, and balloons. At the same time, the Chamber of Deputies provided for an expansion of the laboratory at Chalais-Monville by a grant of 73,000,000; a full-scale wind tunnel was to be constructed, and an engine testing station set up. This sum was in addition to the appropriation of 2,537,000 which was allocated to research, technical development, and prototypes in the 1932 air budget.

The overthrow of the Weimar Republic and the advent of a new but well-known rearmament of Germany produced a temporary expansion of credits for the French Air Ministry. The 1933 budget amounted to approximately 73,000,000 of which about 55,785,000 went to aeronautical research and development. However, as time went on, the Chamber became less nervous about Hitler, and more concerned with saving money and holding down taxes. The appropriations were not greatly increased until 1936, while the sums available for research were cut in 1937, 1938, and only partially restored during 1939.

In 1935 Hitler announced the official rearmament of the Reich, and the following year the Spanish Civil War broke out with Germany and Italy openly intervening. These unhappy events are reflected in French budgets and growing concern in that country over its deteriorating military situation. It was feared, and with reason, that French military equipment was no longer superior as it had been in the twenties, to the planes, tanks, and guns possessed by the potential enemies of France. As a result, efforts were made to bring French science into closer contact with the needs of the army, navy and air force, as well as with the great industrial trusts. Between 1936 and 1939, something-like a scientific and technical mobilization was tentatively projected. Reference has already been made to the Central Service of Scientific Research (1936), the National Center of Practical Research (1938), and the Institute of Scientific Research for National Defense (1938).

Although these organizations dealt in a general way with aeronautical problems, it was felt that something more specific was needed, and consequently the French Association for the Development of Air Research (Association Francaise pour le Developpement des Recherches Aeronautiques) was created early in 1933, and began to function in July of that year when it received its first government subsidy of 233,333. In 1939 it received 841,666. This organization was deliberately modeled after the American National Advisory Committee for Aeronautics, for which the French had a great admiration. Six members were high officials in the Air, Navy and War Ministries; six were eminent scientists, and the remaining seven were the heads of the newly nationalized air industries. The official purpose

19. ibid.
20. Report on Aviation Laws
23. Ibid.
of the Association, as stated by the Air Ministry and the National Society of Aeronautical Construction and Cire priors, responsible for its creation, was "to promote and intensify in France studies, research, and experiments of any sort capable of advancing aeronautical techniques." 24

It was hoped that by a wide collaboration of interested parties, and by a judicious assessment of needs, the Association could assist the existing research in France to bring itself up to date. Three general fields of activity were selected as those where research was most needed. These were (1) aerodynamics, (2) engines and fuels, and (3) testing of experimental models. To initiate its work in aerodynamics, the Association made an agreement with the University of Liége whereby that institution agreed to place its famous Institute of Hydraulics (Institut de Mécanique des Fluides) largely at the disposal of the Association for this type of research. If its laboratories were expanded, plans were made to utilize the resources of other laboratories. The studies previously carried out to develop new motors and fuels were considered insufficient to keep up with other countries. Therefore, it was planned to set up a special motor laboratory at Bricy, near Orleans, to carry out extensive experiments in this field. For the best flying of new models, an experimental center was to be developed near Toulouse where the salubrious climate promised a maximum of good flying days. Finally, to keep in touch with developments not only at home but abroad, the Association projected the establishment of an Aerotechnical Information Center (Centre d'Information Aerotechniques) where reports of the latest ideas and methods could be classified and preserved. 25

Unfortunately, most of these excellent plans came to nothing because they were, in Lord George's famous phrase, "too little and too late." The post-War thirties, France was confused and disorganized. The deep split between the strong and powerful parties that should have been bulwarks of the state became even wider. The extreme left and the extreme right distanced Hitler and feared him, but they hated each other more, and the middle parties drifted first toward one side and then toward the other without finding a haven. Either. The only common meeting ground of a majority of the people was a deep and sincere desire to avoid another war, and a equally profound reluctance to prepare for it. Part of this reluctance was, no doubt, strongly motivated by economic factors, and none of the many ministries between 1933 and 1939 had the courage to propose the additional taxes which an extensive rearmament would inevitably require. In even more serious weakness was the over-confidence in the strength of the armistice which was frequently cited in opposing those who demanded more tanks and planes and higher taxes. The whole national psychology became addled to the fatal idea of a war based on a mere holding of the highest defenses and waiting to see what the enemy would do.

As the crucial year of 1939 drew near, French air budgets continued to be inadequate, and the portions devoted to technical research and aeronautical experiments were even less well provided for.

24. Ibid.
25. Ibid., April 1939
26. This statement is based on the personal observations of the writer while in London and Paris during the Munich crisis.
As early as 1928, a comparison of research funds provided for civil aviation by the governments of France and Germany is highly significant.

<table>
<thead>
<tr>
<th></th>
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<th>France</th>
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<tr>
<td>Technical services research, etc.</td>
<td>122,220,000</td>
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</tr>
<tr>
<td>Technical services installations</td>
<td>27,000,000</td>
<td>6,125,000 (27)</td>
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</table>

During the early years of the Hitler regime, when Germany was making intensive and successful efforts to develop new and improved tanks, guns and airplanes, French governments were reducing the amounts reserved for scientific investigation in the air ministry budgets. Here again, the figures offer a striking testimony to the extent of French unpreparedness.

**Air Budget Expenditures in Millions of France**

<table>
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<th>Year</th>
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</thead>
<tbody>
<tr>
<td>1933</td>
<td>1,600</td>
<td>119</td>
</tr>
<tr>
<td>1934</td>
<td>1,800</td>
<td>77</td>
</tr>
<tr>
<td>1935</td>
<td>2,000</td>
<td>73</td>
</tr>
<tr>
<td>1936</td>
<td>2,200</td>
<td>93</td>
</tr>
<tr>
<td>1937</td>
<td>4,200</td>
<td>150</td>
</tr>
<tr>
<td>1938</td>
<td>3,200</td>
<td>340 (=?</td>
</tr>
</tbody>
</table>

However, when the danger was at last perceived, and an attempt was made to catch up with technical advances in aircraft, it proved impossible to tear off the confusion and sloth of many years accumulation. Furthermore, when the war began, no sound policy of draft deferments was worked out and young scientists and technicians were ruthlessly snatched from laboratories to enter an army that had made no provision for using their special skills anywhere needed elsewhere. In view of the French debacle, the statement of Hans Bade, a Hungarian journalist who served with the French army in 1939-40, is of special importance.

I think there were two things, or three things, that affected the French air power. The first thing was that the French air power was extremely outmoded. They were extremely conservative. They did not use the new inventions. They refused even to inquire or learn about them. The second point was that their air power, exactly like all the other weapons, was not developed because they decided not to make war, and when they were in the war, they decided not to fight in it. (29)

"Michael J. Lentz, a French engineer and economist, testifying about the same time (Sec. 1941), also laid great stress on the scientific and technological unpreparedness of France."

27. Report, ibid., 11.
The French universities and scientific laboratories were not very rich; they were not very well organized and they were not as centered, as in this country, toward industrial research. They were more scientific establishments for theoretical research. Whatevver young men they had went to the Army. . . . The older scientists remained at the university, and unless their laboratory was especially subsidized by the Army or Navy, or any other servicemen, I don't think there was a program of organized mobilization of scientific research.

A final comment must be made on another handicap that restricted the efforts of French aeronautical science to catch up with its more rapidly advancing neighbors. This was the unwillingness of the military and naval authorities to open up their secret, take civilian scientists into their confidence, and give them an idea of the technical employment of their discoveries. The invention of a device to neutralize the German magnetic mine, for example, was held up for some time because the French navy refused to give out a complete description of the weapon. Here is evidence of a serious gap between French science and the French war machine—a gap which the various scientific coordination and integration committees were too late to bridge. In an article in the Time World magazine, Professor Henry Guillermy, formerly of the University of Paris, and now director of the National Center of Practical Research, presents a powerful indictment of the French military for their failure to make full use of French science.

In France, the research branches of the armed forces, until recent years firmly upheld the doctrine that the military, having a marked superiority over the civilians in the knowledge of the weapons of war, and their possible improvements, must monopolize the study of the concrete technical problems of national defense. From these problems they must then extract the implied problems of pure science and give them over, in their crystalline unworldly purity, to civilian scientists to be studied as much and without any consideration of their application to military technique . . . .

The struggle was fought in France against this state of mind with its paralyzing distinction between pure and applied science; reason finally won out, but not completely, and not until the last days of the war—too late, too late. This mental aberration should be fought with ferocity wherever it is met, because it always works against the progress of research and it works against victory.

To conclude, the brilliant beginnings of French aviation before the First World War were not maintained during the interwar period. There were many reasons for this decline, but one of the most important was the failure of French research to keep up with the latest aeronautical discoveries and experiments in other countries. Funds provided by the government were
hopelessly inadequate for research, especially in the period of the thirties. The paucity of money contrasts strikingly with the multiplication of research committees and organizations. If anything, research in France was over-organized. There was little coordination between research agencies, and after 1930 the almost continuous reorganizations failed to establish any centralization. The really sincere efforts made in 1936-39 to bring some order out of the chaos came too late to be effective. By that time, practically every institution in France was suffering from the widespread disintegration and decay that was symptomatic of the approaching destruction of the Third Republic. The research agencies were no exception to this trend, and during their last nine months of existence, during the demoralizing period of the "sitkring", they were able to do nothing to halt the national disintegration.
Part H

RESEARCH AND DEVELOPMENT IN JAPAN, 1914-1939

Historical Background

After a half-century in which the United States acted as a sort of sponsor of the Japanese Empire, this protege surprised the world in 1904-05 by defeating ponderous but confused Russia, emerging from the war a recognized world power. Immediately the United States began to consider Japan a likely rival in the Pacific, while the Japanese themselves felt that it was high time they threw off their swaddling clothes. Events on the Pacific coast of the United States leading to the exclusion of Japanese immigrants deeply hurt the pride of Japan and fired their already growing ambition to become the dominant power in the Pacific and prove that the yellow race was at least the equal of the white. In the years between the Russo-Japanese War and World War I they continued their adaptation to western civilization and industrialization. When World War I began Japan joined her ally, Britain, in the war, and was in position to reap great benefits from the struggle which was to touch her but lightly.

In 1915 Japan prematurely revealed her intentions with regard to her ambitions in the Far East when she presented her Twenty-One Points to China. Under the provisions of these points China would in effect have become a vassal of Japan, and the Japanese would have been able to exploit the vast resources of China to their own benefit. The United States, not yet involved in war, blocked this move, thereby gaining the undying enmity of Japanese imperialists. Japanese territorial gains as a result of the war, however, were considerable, for she was allowed to retain most of the German areas which she had occupied.

The militaristic element, largely dominant in Japan since late in the 19th century, saw the great advancements in military weapons during the war and realized more than ever that if Japan were to retain her place as a great power she would have to gain access to raw materials — raw materials which would not immediately be cut off during a war with some other great power. The obvious source of these natural resources was China, particularly Manchuria.

The rivalry of Russia and Japan in Manchuria had precipitated their struggle in 1904-05, and as a result of the peace settlement at Portsmouth, Japan retained an advantageous position in northern China. As long as Russia was powerful, however, Japan had to be careful in her activities on the mainland lest her policy bring on another expensive war. At the close of the World War and for some years afterward Russia was powerless because of her defeat, the revolution, and subsequent civil war. Great Britain, still an ally of Japan, was grateful for the assistance which the Japanese fleet had given in the Pacific during the war, enabling the British fleet to remain in the Atlantic.

1. Prepared by Capt. Herbert Weaver, AFIHI, April 1945.
to counter the powerful German navy. Unless the Japanese moved too rapidly and with too little tact the British were not likely to interfere seriously with a Japanese penetration of Manchuria.

The only immediate check to Japanese imperialism in Asia therefore was the United States. The Open Door policy, firmly adhered to, had disappointed Japan in 1915, and was likely to be an embarrassing factor in Japanese plans in the future. Relatively stronger than ever before, and firm in her intention to dominate the Far East, Japan in 1917 launched out in a rapid rearming program, doubtless hoping to make herself so strong that no other power would dare interfere with her actions, but failing in that, determined to make war on any country threatening to block her expansion.

To defeat the United States Japan would need a more powerful navy and to that end she bent her efforts. The United States lapsed into an atmosphere of pacifism and isolation and allowed the great war machine drawn from American manpower, industry, and resources, to be dissipated. Only the navy was kept at a respectable high level. Japanese naval activity alarmed both Britain and the United States and the Washington Conference resulted. In bad grace Japan accepted naval limitation; inwardly she considered the naval ratio insulting. Thereafter much of her military activity was in the direction of increasing her already considerable air strength.

Research and Experimentation

Japanese militarists recognized that in general they had not been able to keep pace with the latest developments in war machines and methods. While Germans, French, British, Italians, Russians, and Americans had gained valuable experience with new weapons and devices under actual battle conditions the Japanese army and navy had tended to stagnate. Too little was known of the use of tanks, poisonous gases, and airplanes. Before Japan could bring herself abreast of the western nations in military strength she must also catch up in scientific research, industrial development, and availability of natural resources. Despite what sometimes seemed shortsightedness in Japanese policies, they never lost sight of these objectives. Probably no other nation in peacetime has so assiduously and exclusively devoted its abilities to the problem of making war than did the Japanese after 1917.

It was clear to the literal and rational minds of the Japanese that military strength depended heavily upon science, therefore the Japanese must have science. But it was not quite as simple as that. With but a slight background in technological fields, and lacking a pool from which to draw skilled labor and research men, Japan might be likened to the new rich who try to purchase culture. As a result of this nationalistic singleness of purpose the government and industrial laboratories and institutes are probably larger, better financed, and better organized in relation to the wealth of the community than in any other country. Unfortunately, practically all research and experimentation were along lines of development of war materials and weapons.

Eternally pressed for time, the Japanese fell into the habit of imitation to such an extent that they have never been able to escape an almost complete
dependence upon western nations for basic research. They brought in scientists from all the leading western countries to teach them modern practices and techniques. With infinite patience and persistence they copied the German and Anglo-American scientific methods and systems of research, but in doing apparently suffered from an exaggeration of the bad points of each. Their work was almost completely channelized by the ever-powerful militaristic element of the government. Japanese scientists became over-elaborate, pedantic, without imagination, and in many instances uncritical and inaccurate. As long as they were dominated by a group which held the view that copying saved the trouble of experimenting, Japanese scientists could never hope to close the gap which separated them from the leading scientific minds of the west.

Japanese scientists, of course, were not primarily to blame. Japan was rapidly emerging as a totalitarian state, adopting many of the principles on which the Fascist states of Italy and Germany were founded. Independent thought and research were suspect if not verboten. As the years passed warmongers gained strength at the expense of the liberal elements and science was used more openly and more cynically even than in Europe for purposes of war research, and all scientific study was directed toward preparation for war on a large scale.

Aeronautical research in Japan really began in 1916 when a Commission of Investigation into Aeronautics was set up, with its initial research work being carried on in a division of the Technological Department of the Imperial University at Tokyo. In 1918 the Aeronautical Research Institute was founded as a separate department in the University and housed in its own building. During the earthquake of 1923 the building was destroyed by fire. The government, under the guise of earthquake restoration, appropriated a large sum for a new and more complete laboratory. The site chosen was, significantly, a former experimental farm, and in 1927 work was begun. By 1931 the Institute had fourteen buildings as well as possession of an unused railway tunnel some 300 yards long. Needless to say, research was largely along lines of military aeronautics.

Meanwhile extensive laboratories had been set up in army and navy arsenals. Aircraft factories, subsidized by the government, were equipped with huge laboratories manned by large numbers of scientists graduated from the Imperial universities, many of whom had also studied abroad. As air-mindedness increased the aircraft industry grew, and laboratories were greatly expanded. Control over scientists became so tight that they were forced to take positions in government sponsored laboratories or plants, and industries not actively engaged in the manufacture of war supplies found it almost impossible to obtain competent technical assistance.

In 1939 a Central Aeronautical Institute was established at Tokyo with vast funds at its disposal, and with the objective "to lay by scientific research, both fundamental and practical, technical foundations for the aircraft industry." It was controlled by the government through the Aviation Bureau, and in scope could be compared to N.A.C.A., the German D.V.L., French S.T.A., and Italy's Guidonia. Departments of hydrodynamics, aerodynamics, structural tests, aviation materials, air instruments, aerial experiment,
general affairs, and workshop were established. Little is known of the accomplishments of this Central Institute because of the outbreak of war soon after its establishment. In fact, after 1931 the military supervision exercised over all laboratories has kept the outside world in the dark as to what was actually being done. One military attaché thought the Japanese were secretive because they were accomplishing nothing of value and wished to hide their failure from other countries. While it is probably true that the Japs have not been pioneers in any field of aeronautical research it is also true that they did not always copy blindly. By careful selection and endless experimentation they were frequently able to expand and make improvements on western ideas and machines.

The fact remains, however, that we know only what the Japanese wished us to know about the areas of research in which they were engaged, and have been able to learn practically nothing about the results of their work. In 1931 a military attaché reported that subjects of research at the Imperial University at Tokyo included: possibilities of aircraft without engines; superspeed cameras; X-ray examination of atomic structure of alloys; explosion hazards of gas mixtures; decomposition of shale oil under heat and high pressure; prevention of explosion of hydrogen gas; development of magnesium alloys; study of autogyroscope; tests of engines at high altitudes; comparison of diesel engines as engines for aircraft.

Japanese also did extensive research in nutrition, general metallurgy, and in the field of aircraft fuels and lubricants, generally with the idea of developing substitutes for critical war materials which were not to be found in their homeland. Even in the days when most aircraft were constructed of wood they sought native trees to use as substitutes for mahogany, walnut, spruce, white cedar and pine. That their efforts were not successful is reflected in their huge purchases of woods in the United States in the 1920's; purchases which were so large and made at such a high price that American consumers frequently found it extremely difficult to purchase such woods from American dealers. Attempts were made to develop a lubricant from soybean oil to take the place of castor oil. Japanese sought to obtain hollan from hot springs at Kukui Ken but failed completely. They did, however, succeed in finding a native fabric which was substituted for cotton fabrics in making oldstyle airplanes.

Analysis of captured war materials since 1941 has indicated that the Japanese failed miserably to develop substitute material, but in view of their extensive conquests this failure has not yet affected their war effort. Nickel, tin, magnesium, and aluminum have been used lavishly, while aircraft fuel and lubricants have almost invariably been petroleum products. Apparently they have not been able to approximate German successes in deriving fuel and lubricants from bases other than petroleum, nor in development alloys which do not require the use of imported ores. Furthermore, their war equipment has shown an inability to reach western standards of craftsmanship and originality of design.
Aircraft, Industry and Air Power

As is the case of research and experimentation the Japanese had neither the time nor inclination to depend upon their own products and resources for the development of their air force. Their original air force was purchased in its entirety. They turned to France as the leading example of land based air strength, and to Britain as the leading naval air power. A French military mission to Japan, consisting of pilots, designers, machinists and general technicians, exerted such a great influence that for several years the Japanese army air force was very nearly an exact replica of the French air force, differing chiefly in size. French made aircraft were purchased in large numbers; French organizational and maintenance methods were adopted almost without change. A British naval air mission to Japan influenced the Japanese naval air force in the same way; although some naval planes were bought from Germany, Italy, Denmark, and the United States.

While this adoption of foreign material and methods served as the fastest possible way to equip Japan a great air power, it was recognized that to maintain such a position the Japanese must be made air-minded, and a domestic aircraft industry developed. Too often a foreign model would be out of date before planes could be delivered to Japan. Copying was supposed to be a mere stopgap and the government took steps to put Japanese air power on a firmer basis.

By every possible propaganda means Japanese youth was made air-minded; civil aviation was encouraged, considerable subsidies being granted to young men interested in learning to fly; subsidized commercial airlines were projected and eventually put into operation; prizes were offered for accomplishment in aviation; newspapers sponsored and publicized aerial competition of various types; numerous air defense societies were organized.

Meanwhile the development of an aircraft industry proved a difficult task. Mitsubishi, Nakajima (backed by the Mitsui interests), Ishikawajima (backed by the Wana Company), and Kawasaki yards (representing the extensive Kawasaki interests), were the most important aircraft manufacturers in Japan, as long as the government followed the policy of buying all military aircraft from abroad there was little market for their products. Independent and powerful, they were eventually coaxed, bribed, or blackmailed into self-revelation and into acquiescence to government control. Inducements in the form of promises of government contracts, out-right subsidies, exemption from income and business profit taxes and import duties on approved materials, all were thrown over and gave impetus to a rapid expansion of existing plants and the building of numerous others.

Financial assistance was given the industry in as many devious ways that it is obviously impossible to make an accurate computation, but the amount was enormous. Government money at their disposal in almost unlimited amounts enabled the industry to adopt a relatively high wage scale which attracted labor. Use of the apprentice system aided in building up a corps of skilled laborers. Until native technicians and artisans were trained, however, dependence on foreigners was an absolute necessity, and until the industry itself matured foreign designs were used exclusively. German, British,
French, Dutch, Swiss, and American experts were imported to advise, teach, and direct the huge expansion. In the meantime, large numbers of Japanese were sent abroad to study production methods and techniques.

In their hasty development aircraft manufacturers bought every possible type of foreign plane, engine, and accessory. In many cases they bought the right to manufacture these foreign models, but in other cases they simply made Japanese versions without consideration of patent rights. Military attaché reports during the period mention the following planes as either being manufactured in Japan under patent rights or being copied without regard to patents: Heinkel, Zepplin, Fairchild, Voisin, Junkers, Diriglon, Lorraine, Fokker, Voieville, Gnome, Curtiss, Nieuport, Breguet, Dewoitine, Lockhead, and Blackburn. Engines were: Hispano-Suiza, Salmsen-Motoren, Napier, Renault, Gnome and Rhone, Armstrong-Whitaker, Cirrus, Pratt-Whitney, *right*, Jupiter, Vaux, Farman, Lorraine-Deiturich, BMW, Benz, Rolls-Royce, and Junkers.

By 1927 the industry had made such strides that factories no longer retained such large numbers of foreigners. Practical efforts were being made to develop Japanese planes and engine designs. In the early 1930's foreign planes were imported only in small numbers for the purpose of copying and modification. Aircraft and engines with Japanese names were being made in large numbers, although each one could be immediately spotted as an imitation of a more foreign model. Most of the accessories, however, were still being imported: Straus, Zenith, BMW, Lohner, and Caudel carburetors; Bosch, Lohner, and MFG spark plugs; Latrobe, Eclipse, Breywood, Herter, and Carelli starters; Beach and Biehle propellers; Lambin, and indra radiators; Vickers, Lewis, Denticile, and Curtiss engines; Curtiss-Wright propeller hubs from the Philadelphia Steel Corporation; Sperry automatic pilots; WN superchargers; SKF bearings from Sweden; Farman reduction gears; and Hamel propellers.

Approximately eighty per cent of the machine tools were of American manufacture, and most of the remainder were made in Germany, but the Japanese were beginning to produce their own machine tools. In the mid-thirties military attaché reports were excluded from most of the aircraft factories and from that time little was known of their activities.

The bought-ready-made Japanese air force by 1924 had become a source of anxiety to the United States. In that year General Billy Mitchell visited Japan, reporting that the Japanese were probably second only to France in air strength, and that they were far ahead of the United States. This view would be greatly widened, he said, because of the Japanese building program planned for the next two years. While one is a bit skeptical of this report because of General Mitchell's obvious interest in arousing Congress to increase appropriations for the air forces in the United States, the findings are significant. Partly as a result, the General Staff, in a direct appeal for increased appropriations, said that Japan's aircraft equipment was the most modern of all the great powers; it was of recent construction and considered as a whole was unequalled in quality by that of any other country. Furthermore, her transport planes were the equal of any in existence.
In 1924 the Japanese army air force consisted of 22 squadrons, all equipped with planes manufactured in foreign countries. By 1925 it had been increased to 37 squadrons equipped entirely with planes manufactured in Japan but of foreign designs. Most of them were already obsolescent, and the Japanese had found that in following the policy of merely copying foreign designs their planes were obsolescent almost by the time they were obtained. During the next year the number of squadrons was increased to 53 and many of the obsolete planes retired. A new policy with regard to adoption of plane types was being followed. Instead of ordering large numbers of a particular model and having it become obsolescent before production was completed they began to order smaller numbers, placing orders at more frequent intervals. In this way the air force was equipped with fewer and fewer obsolete planes. By 1937 the air force was swollen to 99 squadrons, of which 21 were pursuit, 16 observation, 13 light and medium bombers, and 4 heavy bombers. A new aeroplane had been adopted. From 1937 on the Japanese air force grew rapidly, and considerable improvements were noted in their aircraft. While some of the newer designs might have been peculiarly Japanese, others were of German origin.

Japanese air force doctrine has followed much the same pattern as the development of the aircraft industry itself. For years nothing new was added that had not already been accepted in other countries. As the industry grew, however, pilots were taught that the aircraft could be procured in such numbers that they could be used without regard to losses -- the mission itself was all-important, not the return of aircraft and pilots.

China provided a proving ground for both materials and tactics as long as there were enough modern planes in China to oppose them. As the Chinese air force became important the Japanese used only sub-ordinate planes and pilots, keeping the better forces in Japan. Developments within their air force were kept secret, and as a result the Chinese had to learn about it -- the hard way -- in combat against them.
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