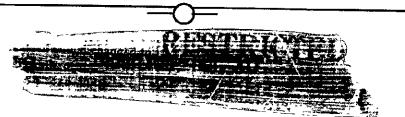


US Air Force Historical Study No. 20

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



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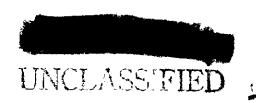
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Prepared by
AAF Historical Office
Headquarters, Army Air Forces
June 1945

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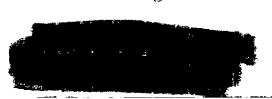
POLICIES AFFECTING AIR MATERIEL, 1915-1944

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

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Marwell AFB, Alabama

Prepared by
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June 1945



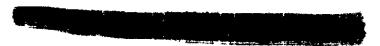
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COMPARATIVE HISTORY OF RESEARCH AND DEVELOPMENT POLICIES AFFECTING AIR MATERIEL, 1915-1944.

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PART A: ABSTRACT

The statement that "during the period 1918-1959 no new weepen was developed by or for the Armed Forces" is not berne out by the facts unless one insists upon the narrowest interpretation of the word "new."

Virtually each of the 100 or more tastical simplans 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 fire power or striking power in comparison with its prodecessors. The differences between the Martin bomber of 1915 and the Bosing IB-15 and Y1B-17A of 1959 are toe west not to label the latter articles as new by contrast. Likewise the power plants, the armament, and the electronies equipment installed in the combat airplanes in 1989 bore little resemblance to these in use at the end of World War I. Likewise the standard engines, propellers, bombsights, turrets, and radio equipment of 1939 had little in common, in terms of performance, with their lineal ansesters of 1918. (pg. 52-38). 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 1989: 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 reaket propulsion, being studied under an Air Corps contract since December 1938 (p. \$5).

How many of these aeronautical frontiers of 1959 were "new" if compared with the progress among the various foreign air ferces in another matter. By 1959 Italy had apparently already achieved working models of a jet-propelled plane (pp. 164-165), whereas America had not quite reached this stage. England's "radio locator" was probably more advanced in 1959 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 Corpe (p.54).

How effective the AAF has been over the last 50 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

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are more similarities than differences. The research and development systems of the various military establishments throughout the world have had as many aspects in sommon as aspects that were dissimilar or unique. Thus, the whole body of procedures lossely 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 organised into a division by that name, an sir 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 or 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 semmon to autocratic and democratic nations alike, and common to World War I, World War II, and the years of peace in between: seamon in the sense that conflicting demands and priorities arose that reflected conflicts between development of the new standardisation of the eld; between demands for quality and demands for quantity; between one field and enother (for example, aerodynamics vs. electronics, and internal-combustion power was jet propulsion); and between military plans and civilian sources of scientific research.

Tational attitudes

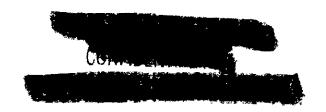
American appreciation for scientific research has probably been more vocal in the fields of the "practical" seiences than in "fundamental" or "pure science," difficult as it is to dissociate them. Edison, Ford, and Kettering are all well-known names in the last 30 years of American history; scientific "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 Pield, and the wind tunnels at Lengley Field. Much of this interest stems from a spontaneous curissity of Americans toward new mechanical devices, but it has also been sultivated 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 sause 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 Seviet 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 propegands 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 Masi government did not alter appreciably (pp. 132-134). But whether it was shared by the general public is debetable. 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 acronautical 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 merchautics, 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 1935, and the popular consciousness and enthusiasm developed in those countries was usually carried ever to military meronautics as well (pp. 151, 85, 138, 174). French and British sentiment for military aviation began to increase about 1956, but American opinion was not to become consistently favorable until 1939 and 1940 (pp. 174, 99).

Mational 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 propagands, publicity, and public education: in Germany, Italy, and Japan in terms of national self-sufficiency and national superiority (pp. 138, 134, 185); 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

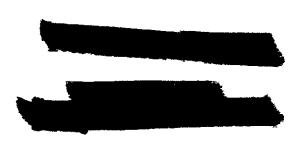




technological accomplishments in World War II has been publicised not only as a tribute to America's wartime progress but also as a guide for the conversion of her "swords" back to "plowshares."

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" science (pp. 21, 54-55, 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 seronautics, the Deutsche Versuchsanstalt fur Luftfahrt (DVL), felt it necessary to defend itself against the charge of being "an unproductive scientific-theoretical organization" (p. 156). 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 Mational 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 notive, 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 semetimes less interested in profit and money renuneration 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 dovernment 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" (op. 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 seconomy, and between the demands for quantity as against the quality of the airplanes and meapons. Both in Italy (pp. 161-162) and in America, for example, and probably in other countries as well, there were frequent pressures for standardisation as against experimentation. Thus McCock 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. 50-51). 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



Another type of pressure was the resistance to the development of the heavy bember in the 1920's and early 1930's, arising from conflicting strategic and testical 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 bember program in 1953 (pp. 31, 38); and to undertake a 5-year program in 1959 (pp. 39-40). After 1940 there was no appreciable resistance from higher authority to the experimental program, and thoughout 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 apsthetic to military meronautics. Between 1908 and 1913 the United States was 14th among the nations in terms of government subsidies for meronautics (p. 25). Not until after war came in 1917 did Comgrees begin to support Army A_istion 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. 51, 45, 46), in spite of the emerging period of peacetime "Normaloy" 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 1938 (p. 138). British political support, which dropped in the later 1920's, began to be revived about 1936, after three years of watching the growth of Masi 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 1950, however, the appropriations for the NACA fortunately rose steeply (p. 58); after 1934 the Air Corps too was again being favored (p. 46); 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





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"war" period down to the present (pp. 46, 99). By 1942 appropriations were se adequate that some AAF officers sould "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 prises and subsidies to civil aviation (pp. 156, 169-178). In America it was a common practice in the Air Corps before 1939 to permit the contractor to amortise experimental costs with inceme from future production orders (pp. 70-72). Another element favorable to the research budget in most countries was that thepay of military officers engaged in experimental work did not appear in the research budgets (pp. 29, 47, 59).

By 1959 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; 8/10 of 1% in the Saviet Union; only 1/10 of 1% in Great Britain; and perhaps 3/10 or 4/10 of 1% in Germany, (p).55, 125). Since 1959 America probably has had no peer (except perhaps in the Seviet 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 1959, only a small fraction could be charged to military and naval projects. This "total" conversion of increase science to war was comparable to the conversion of other elements of the national economy, and all of this expansion reflected a "bandwagen" policy of financial support for the military programs in wartime. Once aroused, the United States had no peer in lawishing financial support on its war machine.

Organisation.

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-



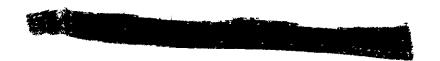


ment of airborns accessories and ground equipment is a seeperative project, involving (in the case of the AAF in World War II) the Air Staff, the Air Technical Service Command, the Proving Ground Command, the Maticnal Defense Research Committee, industrial laboratories, university scientists, and sometimes 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 McGook Field. There was, however, a Mational Research Council for mobilising scientists and industrial laboratories that were not already under contract to the Army and the Mavy. Not only did the Air Service "cooperate" with the MRC: it took over the entire MRC 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 MACA 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 1950, and by 1959 it probably had ne 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 Agrenauties, established in 1926 as an endowed foundation and destined profoundly to affect meronautical education throughout the United States. Still another scientific group was the Mational Research Council and its "parent body," the National Academy of Sciences, concerned with fields other than aeronauties. Their war committees were demobilized after 1918, but the main organisation survived as a "scientific edvisor" to whatever Federal agencies chose to use their services. Although they regarded their rele as passive, the NRC and the HAS did spensor a limited number of projects for the Air Corps before 1939 (pp. 79-81).



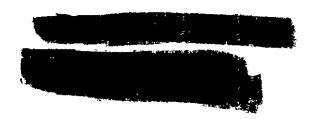


The Army air arm's organization for research and development has been relatively simple and consistent throughout the whole period 1917-1945. Thus, the ultimate sontrol and supervision of the research and development program has been in the precurementtactical arm, with its authority stemming from the 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, bothin the AAP'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 Mational Research Council, the Mational Academy of Sciences, and the National Defense Research Committee (pp. 29,113-5). Oceasienally there were reorganisations 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 erganisations of scientific sommittees, councils, and assocations 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).

it the same time there have been elements of organization that were rather uniform among all countries. Meet of them had a MAGA 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. Meet of them, tee, had a Mational Research Council, such as those in Germany (1912), England (1915), the United States (1916), Italy (1921), and France (1922) (pp. 185, 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 miroraft,



automotive, and other industries, together with scientists like William and denderhall, were given military commissions or civilian jobs in the mir Service in connection with research and experimental projects (pp. 20-28). 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 emong them, both officers and civilians, frequently came from america's best technical schools and in some cases from industry, and their training was sup lemented (for the officers) by the Ingineeri g School at right Field and by civilian institutions like Ma Ia Tay Gala Techan Michigan, and Stanford (most of them endowed by Guggenheim) (pp. 44-45). Officer attendance at such schools was authorized by Congressional legislation unsurpassed enyshers 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 sirgraft and related industries. In Norld War II many right Field civilian experts were given military consissions, and were supplemented by aeronautical engi eers commissioned from industry and by other acientists brought in both to Wright Field and Washington, including groups like those of Dr. Zdward L. Bowles and Dr. Theodore von karmen 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 "ar 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. 180), while Cermany 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).



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Another practice for improving material development has been to import scientists and other specialists from abroad. The Soviet Union (P. 148) and Japan (p. 186) in earlier years were the outstanding examples of such a conscious policy. After 1955, 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 standardisation 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. Itsly was not able to produce its unique jet plans, 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 resources for propoduction 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, izreconcilable 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 mircraft 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 sutside 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 passetime 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 prejects 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 economic 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



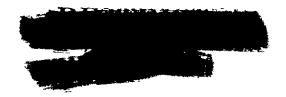


Field. This material center is primarily a monitor of industrial research rather than an independent laboratory; and the continuous problem both at Wright Field and in the air staff in Washington is to effect the best compromise between experimentation and production, between quality and quantity, between striving for perfection and falling in obselescence. In addition, one specific Air device for rationalising these pressures should be mentioned—the system of modification conters 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 meapon 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 Mation's military power, in terms of the potential enemy? And what are the tactical needs in terms of weapons and counterwespons necessary for meeting the known and anticipated power of that enemy?

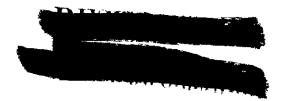
On the eve of World War I the small nucleus of airsen in the Army were aware of the tastical and strategic functions of air power, but no combat plane had ever been designed or built in the United States up to that time. World War I itself was for the American Air Service an operational problem on the 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 symbolised the rise of independent strategio thinking in the Army Air Service, and the dootrines of strategic bombardment expounded by Mitchell and others became the foundation for the Air Gorps research and development program in the 1920's and 1930's (p.31). In 1933 the Drum Board approved the air war plan for operations to be based on the American continent, to be directed first toward Buropean targets and ultimately toward the Far East. The Boards 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-I5 and XB-17 were begun, and the Air Corps research and development program began in earnest, contered around this fundamental bombardment mission (pp. 38-39). The development and testing of these two models between 1938 and 1939 led directly to the heavy bembers that were used in the European theater after 1941 and the long-range very heavy bumbers used in the Far East after 1948. The wartime improvements of these experimental bombers after 1959 were, of course, substantial and vital, but they were based not on any fundamental change of strategic doctrine. Instead, they represented solutions to tastical difficulties and problems encountered by the HAF 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 thwaters 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 releatlessly with the ground and air—ecoperation operations across the Continent after June 1944. Mad 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 wital as the development of our own strategic measures.

Whether America's present air weapons are adequate for coping with future strategie 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 wrapons now under development -- the new very long range bombers, the most advanced radio and radar sids, 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 80 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 utilisation 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 insure that industry remains in a stand-by condition both for development of new weapons and for their production in quantity when the need wrises.



Part B:

RESTARCH 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 procision and effectiveness.

The principle that the quality of the air force's airplanes must brecede 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 Mavy for spending too much money on experimental work and not enough on quantity procurement." Army air spokesmen, saddled with an inventory of rapidly obselescing 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 (em

^{1.} Prepared by Dr. Martin P. Claussen, AFIHI, 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 Science (482 pp., New York 1939; 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 Mational Archives Bldg., Washington, D. C.

^{3.} Report of the Federal Aviation Commission/Howell Commission, Jan. 1985, p. 127. The Howell Commission went on to say that new, in 1935, "the Services are in danger of switching to the opposite extreme." Ibid.

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, reviewing 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 continuing research and development policy was needed; that, in comparison, the problem of quantity production requirements was "not a difficult task"; and that

4. Memorandum for Maj. Pettis, OAS/W, by Gen. Mason M. Patrick, Chief of the Air Service, 26 Feb. 1923, in AAF 475.73 Aeronautical 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 beards 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 Federal 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 Historical Studies Mo. 25, 131 pp., Dec. 1944), passim.

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 AC budget should require 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.

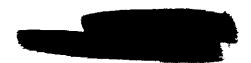
7. Materiel Division, study on "Aeronautical Research and Development," no date, about 24 April 1939, 3 pp., in AAF 400.112
Tests and Experiments (U). The wording is slightly different in the final draft of the Air Board report, "Air Board Report," AG 320.2 (6-26-39), 15 Sept. 1939, tab C, p. 2; missographed copy in A. J. Lyon project book No. 15-A, in office of Deputy AC/AS MES.

Pailure of the production 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 activiti s of the Air Corps, and it was a budgetary rubric common to all the supply services of the army in 1939. Essentially it mount (for the Air Corps) the engineering, research, and testing at Fright field in connection with the construction by industry of per or improved models of sirplanes, engines, and airborne and ground equipment peculiar to air operations. It was occusionally subdivided by the Air Corps, in the directive and correspondence, into "fundamental research," such as aerodynamic analysis in wind tunnels, and "applied research," Neither of thes sub-meading was exclusive, however, nor was the distinction always accurate. For example, wind-tunnel tests, far from being studies in "pure acience" 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 werlal weapons in total war potentially included research in all the natural and physical sciences, in both their "pure" and their "practical" phases. The \ir 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 the saifications of knowledge they apparently did not betray

^{8.} Ibid., tab G, "Policy Coverning Research and Levelopment,"
p. 1. The observation on production requirements, which was omitted from the final draft of the report, appeared in memor anount of proposed recommendations of the "Loard," no date, about May 1939, in AAF 400.112 Tests and Experiments (U).

^{9.} Another /C elassification in 1939 was "fundamental" (NAC/), "applied," (Kright Field), and "university" research, entirely emitting 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

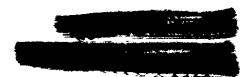
More important than a pigeonholing or comparamentalizing of research and development was the fundamentally cooperative character of science in war (as, indeed, of science in peaceful pursuits), Fspecially was this true of experimental airplanes, whose complex design and construction problems had been 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.

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 MACA and Wright Field, flight and static test reports from Wright Field, operational suitability tests from the Air Corps

Report of the Federal Aviation Commission /Howell Commission/, Jan. 1935, pp. 162, 167. The Commission had used this descriptive analysis to demonstrate the need for combining the functions of experimental construction and quantity production in a single give: 'reraft firm.

^{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, 255 pp., 1737; as well as later volumes on Industrial Research and on Business Research.



proving ground. 12 suggestions for modification from the tactical units of the Air Gorpa and (after December 1941) 15 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, mavigation, and other airborns 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 postwar 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 Sovernment, the other supply services, their industrial and university contractors, and the research stations of the other Allies.



^{12.} That is, the 23rd Compesite Group, activated at Maxwell Field in August 1939 and moved to Mglin Field, Fig., in Dec.; and an "ancester" of the AAF Proving Oround Command. See PGC, Mistorical Branch, "Bistorical Outline ..." (Jan. 1945), pp. 19, 20.

^{13.} Actually, suggestions for modifying simplemes 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 Rission (Army Special Observers Group* after June 1941, were concerned in large part with analysing the combat performance and effectiveness of U.S. - produced air material (both Lend-Lense 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 (6) the recorded intellectual experience, whether buried in publications. archives and records, or umpublished manuscripts. If there is any truth in the resertion 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 periodicels were being published throughout the world, 14 and their utilization was far from adequate either for peacetime or for wartime purposes. Even abstracts of this literature, like Chamical Abstracts, were not being fully utilized. Added to this were the mountains of unpublished manuscripts in adademic, 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

^{14.} World List of Scientific Periodicals, 1934 ed. Problems of scientific publications are discussed critically in J. D. Bernal, The Social Function of Science (London, 1939), p. xv. 117, 118, 272 ff., 292 ff., 449-457.

^{15.} Mational Resources Committee, Relation of the Federal Government to Research (1939), p. 53.

II. RESEARCH AND DEVELOPMENT POLICE'S 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 1892 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 spwing 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.

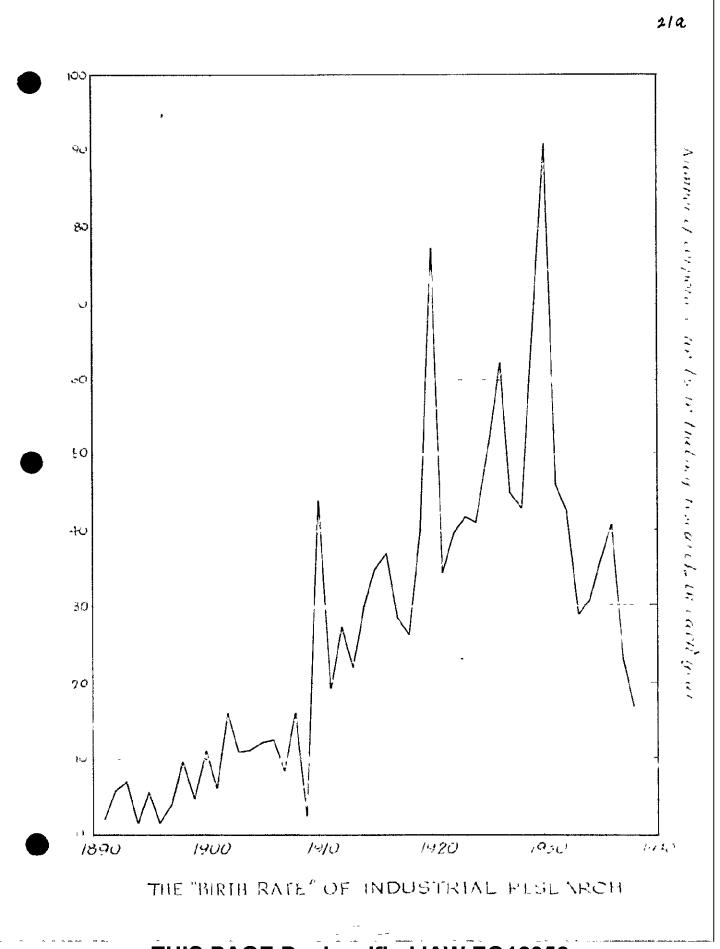
Industrial research was notivated by profit, of course, and had flourished in industry before 1914 largely because of the growing appreciation that better or new products would command a better market in the competitive world. Sometimes this notivation had an adverse effect on the exploitation of inventions? 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 Bessener process

Graph taken from Franklin S. Gooper, "Location and Extent of Industrial Research Activity in the United States," in Mational Resources Planning Board. ... Industrial Research (Washington, 1941, 370 pp.), pp. 176.

^{2.} So 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 inventions between 1889 and 1929 come out of corporate laboratories, according to one critic, J. D. Bernal, in the Social Function of Science (London, 1939), p. 161.

Hearings conducted by Louis D. Brandeis, 1912, quoted in J. D. Bernal, The Social Function of Science (London, 1939), p. 143.



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all had resulted directly from military and naval needs. A 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

Asronautics by 1914 was the letest field where scientific development was being financially spensored primarily in connection with war and national preparedness, but it was in Burops 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, wastly 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. 5 Furthermore, in 1898 it had been the Army and Kavy 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. Hewever, im 1903, when Langley's machine failed to launch, the newspapermen who were present dammed 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 am offer by the Wrights to sell their plane to the Government was rejected, and not until after they sold their ideam 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.7

5. National Resources Committee, Relation of the Federal Government to Research, (Vashington, 1939), pp. 44-45.

7. AFIRI Historical Study. *A Brief History of the Army Air Forces* (1943), by Joseph Reither, especially pp. 23-24, 29-32.

^{4.} J. D. Bernal, The Social Function of Science (London, 1939), pp. 165-170. Bernal, a critic in 1939 of the "prostitution" of science to war, acknowledged that the "majority" of technical and scientific advances in the 19th century had sprung from military and naval needs (p. 165).

Frederick S. Hayden, <u>Aeronautics in the Union and Confederate</u> <u>Armies. With A Survey of Military Aeronautics Prior to 1861.</u>
 Johns Hopkins Press, 1941, 421 pp.

These modest beginnings were followed by additional purchases of airplane 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 \$66,570,000 spent between 1908 and 1913 throughout the world for military (and maval) 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 ampenditures of several of the minor powers: 10

Germany	\$28,000,000
France	22,000,000
Russia	12,000,000
Italy	8,000,000
Austria	5,000,000
Great Britain	3,000,000
Belgium	2,000,000
Japan	1,500,000
China	700,000
Dolgaria	600,000
Greece	600,000
Spain	550,000
Brazil	500,000
United States	435,000

If the government was parsimonious in subsidizing aviation development, commerical 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, "Il Stated in terms of aero-nautical 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. Mistorical Section file 452.1 Airplanes, General.

^{9.} Arthur Sweetser, The American Air Service. (New York, 1919),p.25.

Sweetser, <u>The American Air Service</u>, p. 16, quoting testimony before House Committee on Military Affairs in 1913. Figures later published by the HACA (in 1943) vary slightly: Germany \$32,000,000; France, \$25,000,000. <u>Journal of Applied Physics</u>, Aug. 1943, p. 399.

n. 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 citiven has endowed an aeronautical laboratory as has been done in many instances abread; our technical colleges have not offered opportunities for the scientific training of aeromantical 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 Bational 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 BACA have been described as follows:

In 1913, Dr. Charles D. Walcott, then Secretary of the Smithsonian Institution and a member of the Mational 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. I. Chambers, Glean Curties, Orville Vright, Dr. Walcott, and efficers of the Army and Mavy. Only three meetings were held when the Comptroller of the Treasury.../ruled/ that the committee could use no government funds mer 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 sviation 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 aeromantics 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 Mayal appropriation bill, which was

^{12.} Sweetser, the American Air Service, pp. 18-19, quoting an unidentified official report of 1915.

passed by Congress and became law March 3, 1915, and the Mational 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 sens misgiving and an abundance of caution, appropriated \$5,000 a year for five years, or "se 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. 15

Vartime 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 pertion 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 wartine activities of the NACA were less premiment 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."

^{13.} Official view of the EACA in Aug. 1943, in Journal of Apolied Physics, Aug. 1943, pp. 399-400.

^{1.} MACA, Annual Report, 1919, pp. 13-14; and Lt. Rebert C. Hilldale, "Mistory of...Aircraft Production...Advisory and Co-operative Agencies" (Air Service historical monograph, m.d., about 1919), pp. 1-37, in A. S. Mistorical Section files. Another function, that of "meromentical intelligence," was established in 1918 for the collection and dissemination of information on American and foreign meromentical developments, and included a "scientific attache" 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, "Mistory of Langley Field" (Air Service historical monegraph, 18 Aug. 1919), in A. S. Historical Section files; copy also in AFIHI.

The Aviation Section's "Engineering Organization" in Vashington, 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."

As the alternative, the McCook Experimental Field at Dayten, Chio. was selected in 1917 because of its preximity 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. M. A. Deeds, Dayton industrialist in the Air Service, Specauses of his airplane and other interests there. Some important laboratory facilities were built at McCoek 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. By November 1918 the experimental engineering personnel of McCook Field totalled 14 officers and 1,335 civilians. experimental Engineering Department, under Lt. Col. Howard C. Marmon (ex-Nordyke-Marmon), was kept quite separate from the *Production Magineering 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. V. Hash (ex-General Meters) 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 Mavy, which was included in the original plan. The Mavy, however, also abandoned Langley, in favor of the other side of Chesapeake Bay. See "History of Langley Field" cited above; and MACA Angual 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 350.05 McCook Field.

^{5.} Compared to production engineering, which had 26 officers, 230 civilians, and and abusiness and military, which had 18 officers, 250 civilians, and 267 emlisted mem. See historical questionaire, 7 May 1919, returned by Engineering Division, in A. S. Historical Section file 260.05 McCook Field.

May 1918 and headed by John D. Ryan (ex-Anaconda), 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. 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—Curties (airplanes) and Wright-Martin (engines); and the whole industry could muster only \$,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 sonly a handful of Americans had ever seen one.

The source for airplane design data in 1917 was, therefore, not American industry but the Allies in Murope, where combat-type planes had already seen action. Major R. C. Bolling was sent to England. France, and Litaly in June 1917 with a mission to select models and to obtain data and samples of material. Accompanying him were several Army and Many 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 might bomber, the Bristol fighter, and the Caproni bomber. Of these, the first two models were to reach quantity production before the

^{6.} Organization chart of Airplane Engineering Division, Bureau of Aircraft Production, Nov. 1918, in A. S. Historical Section file 360.05 McCook Field. After the Armietice, about March 1919, Materiel functions were reorganized into the Engineering Division (Col. Thurman H. Bane, Chief), which was a consolidation of the BAP and of the Technical Section of the Director of Military Aeronautics. A small "Supply Group" was established in Washington about the same time. hagineering Division, Assual Report, calendar year 1919, p. 1; copies in Pentagon Library and in AFIHI.

^{7.} The automobile industry supplied "the lion's share" of engineering telent, 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.

^{8.} Tabulation, *U.S. Army Airplanes Accepted from 1908 to January 1, 1919, *In A. S. Mistorical Section file 452.1 Airplanes, General; Edgar S. Gerrell, The Measure of America's World War Aerosamtical Lifert (Northfield, Vt., 1940), p. 2; and Arthur Sweetser, The American Air Service.... (New York, 1919), pp. 45, 189, 251-252.

^{9.} See R. M. McFarland, *...History of the Bolling Aeronautical Mission*
(A. S. historical monograph, 29 Oct. 1919); covies in AFIHI and in
A.S. Historical Section file 334.8 Bolling...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. Nost of the amerimental sirplame work at McCook Field in 1917 and 1918 was concerned with modifying Muropean 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 automobils firms and from the Bureau of Standards as well.

As to air instruments and accessories, some of the wartime developments actually did reach the production stage, notably self-scaling 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 McGook 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, Eastwan, 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. This group, which

^{10.} Lt. Robert C. Hilldale, "History of...Aircraft Production...: Advisory and Co-Operative Agencies" (Air Service historical Monograph, m.d., about 1919), pp. 113-120 and appendix; <u>Sweetsex</u>. The American Air Service, pp. 64-65, 191; and Edgar S. Gorrell, <u>The Measure of America's World War Aeronautical Effort</u> (Northfield, Vt., 1940),

^{11. *}History of the Bureau of Aircraft Production* (A. S. historical monograph), microfilm copy in AFIHI; and Arthur Sweetser. The American Air Service. up. 176-177.

^{12.} See the following Air Service historical monographs (in A. S. Mistorical Section files): "Science and Research Division," m.d., about Dec. 1918; "A Brief Mistory of the Organization and Activities of the Science and Research Department of the Bureau of Aircraft Production," n.d., about 1919; and Mt. Robert C. Milldale, "Mistory of...Aircraft Production...; Advisory and Co-Operative Agencies," n.d., about 1919, pp. 55-74. See also Mational Research Council annual reports, in Mational Academy of Sciences, Annual Report, 1917, p.47; and 1918, pp. 70,105.

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 Experimentation, 1919-1933

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 yours. 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 MAGA's first wind tunnel, financed by wartime mopropriations, 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; \$11,302,266 was expended on experimental projects during the whole wartime period from 1917 to June 19191. These expenditures were exclusive of additional sums such as the pay of military and civilian personnel, and were invested chiefly in the laborstory facilities and equipment at McGook 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:

The total expenditures of the Air Service (Materiel, training, pay, etc.) were \$1,047,107,458, out of appropriations totalling \$1,691,854,758. Edgar S. Gorrell, The Heasure of America's World War Aeronautical Effort (Northfield, Vt., 1940), pp. 9.8.

^{13.} The National Research Council, apparently inspired by several civilian accentists 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 1915, one year after Britain entered the war.

^{2. &}quot;Comments on Principal Airplanes Considered for U. S. Army Use
During the War of 1917" (A.S. Historical Section tabulation, m.d.,
about 1919), in A. S. Historical Section file 452.1 Airplanes, General. This list includes also a number of experimental trainers,
and unidentified Gallaudet and Albree models.

1-nlace "service" mirplane Ordnesce D 1-place "service" mirplane Stout momorlane 2-place observation Lepere 11 3-place fighter Lepere 12 2-place fighter Localing Thomas Morse MB-1 and MB-2 2-place fighter Thomas Morse MB-3 1-place pursuit 2-place nursuit Curtiss biplane 3-place pursuit Curtiss triplame fighters, based on British Bristol USB-1 and 2 fighter-bomber, based on British DR-4 USD-94 and B Glean L. Martin bomber, 2 engine J. Y. Martin day bomber, 2-engine 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, acrial torpedoes, armament, and bombing equipment.

Post-war experimental activities between 1919 and 19234 were specially tignificant 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 bembeight development problem, for example, the Surply Group in Washington had this to say late

^{3.} A total of 27 airplanes were actually designed and built at McGook Field, including the following:

bombers: USA-D-9, 9A, and 9AB; MB-1A (12 articles)

Attack: GA-1 (2 articles)

Pursuit: PW-1, 1A; TP-1; TW-1; USA-G1; VCP-1 (8 articles)

Observation: GO-1; GO-2 (4 articles)

Racer: R-1 (1 article)

^{4.} The ragineering Division published a secret report on 1 Nov. 1923, entitled "Special Report to the Service." which is virtually an encyclopedia of all air material 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 passes 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 soulonent.

Commenting on the same general problem shortly thereafter, the Chief of the Ungineering Division complained to Colonel Wimperia, the Dritish bombsight pioneer, that experimental work is America was suffering in the post-war period:

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 1920's. For the rest of the decade even quantity procurement suffered, and the experimental budget reached its lowest peak in 1927, ironically most the moment of the Nation's greatest financial "exhilation". 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 Boring for design data for the heavy and long-range bombers. This peacetime research and development program for bombardment, begun 6 years before the Muropean 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 AAF became a combat arm in 1941.

^{5.} Memo for Ragineering Division by Acting Chief, Supply Group, 3 Oct. 1921, in ATSC Central Files, quoted in ATSC historical study, "Development of Bombing Equipment" (draft, March 1945, by Virginia Tools), Chap. III, p.5.

Letter, Chief, Engineering Division, to Col. H. E. Wimperis.
 British Air Ministry and Imperial College of Science, 17 Feb. 1922,
 in ATSC Central Files, quoted in <u>ibid.</u>, Chap. II. p.8.

III. GROWTH AND ACHIEVEMENT BY SEPTEMBER 1939

Developmental Models of Air Materiel 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 seronautics "from a purely scientific view-point," labelled the situation "from a national defense view-point... 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 Gorps 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 indistment 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, 5 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

^{1.} Baker Board, Report, July 1934, p. 72; Federal Aviation Commission (Howell Commission), Report, Jan. 1935, p. 127.

^{2.} ESMR no. 50-461-351, 13 Aug. 1939, "Future Aeronautical Research and Developmental Problems," in E&S file on "FY 1941 RAD Program!"

^{3.} New York Times, 10 Jan. 1939, 8:2, 13:2; 13 Jan., 8:6; 18 Jan., 27:4; 15 June 1939, 9:2.

^{4. &}lt;u>Ibid.</u> 2/ 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 "incessent attack ... upon the Phopelessly 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 sealots" (Report, p. 10).

^{6.} For the inventory of all adopted, developmental, condemned, and obsolete planes in Sept. 1939, see "War Department Special Quarterly Report of Airplanes; Status of Regular Army, Organized Reserve, and Mational Guard Airplanes," 30 Sept. 1939, passin (copy in AFIHI-AH).

^{7.} Total mirplanes of each model on hand in Sept. 1939 (ibid.): 213 B-13s, B-13as; 202 A-17s, A-17as; 68 P-35s; and 171 P-36s, P-36as, P-36Bs, P-36Gs. 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 simplenes built and delivered during the year "- the North American XB-21 with turbo superchargers and power turrats"; and the Stearman XA-21 attack borber. 10 Of the total of 24 developmental models (both "experimental" and "service-test") on hand in September 1939 11, only 5 of them were assimed 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 their close similarity to older, standard models:

KB-21 medium bomber (North American), 1937;

F1-21 attack bomber (Stearman), 1939;

Y1B-17A heavy borber (Boeing), similar (except for engines) to XB-17 of 1935;

AP-37 pursuit (Curtiss), built in 1937 and based on older P-36;

XP-41 pursuit (Seversky), built in 1930 and based on P-35 of 1936;

IFM-1 pursuit (Bell), built in 1927;

XG-35 transport (standard Lockheed "Electra"), modified in 1936 for use la 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

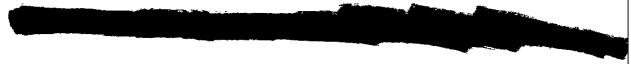
9. Other characteristics of XB-21: 2 Pratt and Whitney R-2130 engines, each 1,400 hp, 14 cyl; span 95, length 61,400 hp, 14 cyl; span 95, length 61,400 hp, height 14,9%; weight 19,080/27, 255 lbs; spd 195/220/-mph; climb 10/10,000; ceiling 25,000/-1; range 1,950 miles; bomb load, 4,000 lbs.; 5x.30 machine guns. MD, "Characteristics and Performance" 1 Jan. 1940.

10. Characteristics of XA-21: 2 Fratt and Whitney R-2130 engines, each 1,400 hp, 14 cyl.; span 65', length 53'1", height 14'2"; weight 12,760/18,257 lbs.; spend 230/257/-mph; ceiling 20,000/'; range 720 miles; bomb load, 2,000 lbs.; 6x.30 machine guns. ND, "Characteristics and Performance ...," 1 Jan. 1940.

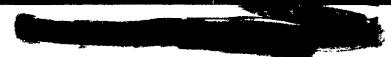
11. 24 models, totalling 62 airplanes; there were more than one article of some of the models. "Mar Department Special Quarterly Report of Airplanes." 30 Sept. 1939.

12. The XB-15 was assigned to the GHQ Air Force; the XP-40, to "miscellenous."
"War Department Special Quarterly Penort of Airclanes ...," 30 Sept. 1939.
Dates are from MD, "Characteristics and Performance ...," 1 July 1939.

13. The XB-19 "flying Taboratory" completed the list of experimental planes on contract. MD, "Characteristics and Performance ...," 1 July 1939.



^{8.} A later statement by the AAF (Hq. MC memo, "Research and Development in the AAF," no date, prepared by "Maj. D." about Feb. 1943; in NAS file "700.430 Kilgors 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 MD, "Characteristics and Performance of U.S. Army Airplanes," 1 July 1939, sheet A; copy in AFIHT.



This total inventory reflected in large part the bud retary situation of the Air Corps. As explained later in retrospect, "so large a proportion of the measur 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 / cr two? / was all that was possible in 1939." 14 Once the budget was increased, to \$10,000,000 i 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." 15

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. 16 The best-performing Air Corps pursuit, the XP-37 (340 mph) was, judging by the Kilner Board evaluation in June 1939, far behind the German ML 109-R (469 mph) and HE 112-U (440 mph), but not far behind the British "Spitfire" (362 mph), and ahead of the Italian Yc 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-201 (347 mph)--were ahead of the French Bloch 170/174 (323 mph), the Italian Ba 55 (267 mph), and the German JU-37 dive bomber (250 mph). Finally, the speed of the fastest heavy bomber (the XB-24, 228 mph) topped the British "Short Sunderland" (210 mph) and perhaps also the "Stirling" and "Manchester" 17; but trailed both the Italian P-103 (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-3350-5, which was planned for installation in the YB-19 ordered in 1939; and 1,600 and 1,700 hp had been

^{17.} Stirling and Manchester are not listed by the Atlner Board, but see ibid.



^{14.} Hq. NC, memo, "Research and Development in the AAF," no date, prepared by "Maj. D." about Feb. 1943; in MAS file "700.430 Kilgore Committee-Office of Technological Mobilization."

^{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 Kilner 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 UD chart, "Characteristics and Performance of Foreign Airplanes ..., " 15 Jan 1933, in AAF 452.1 "Bulk".



reached in the Wright R-2600+3 and 7, planned for use in the B-23, A-20A, and A-20a. Take-off ratings between 1,000 and 1,200 hp, however, were the too limits of engines actually installed in both developmental and standard airolanes, as of about September 1939. In most cases these ratings had already been achieved in 1937 or earlier: 18

1,000 hot Pratt and Whitney F-1830-11, in XB-15 (1937)
Wright R-1820-51 and 53, in B-18A (1937), Y1B-17A (1939),
and C-42 (1939), and planned for B-17B
Allison V-1710-7, in XP-37 (1937)

1,050 hm: Pratt and Thitney R-1330-13, in P-364 (1938) and XP-42 (1939)
1,060 hm: Allicon V-1710-19, in XP-40 (1939)
1,150 hm: Allicon V-1710-11, in XFM-1 (1937), YP-37 (1939), and
XP-39 (1939), and sicilar engines (sub-models 27,29, 37)
planned for YP-38 and YP-39

1,200 hp: Prott and Whitney R-1330-13, 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 XB-24 and YP-43
Pratt and Fritney R-2180-1, in XB-21 (1939)

These horseneser ratings did not represent the actual frontier of research in power plants in 1939, because there doubtless were under development is proved 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 as a university research project since December 1934, under an agreement between the Air Gorps and the National Academy of Sciences.

As to air ordnance, the maximum bomb weight of the advanced airplane models ranged as follows: 8,800#, YIB-174; 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 n "flying laboratory". The maximum usable bomb size was only 2,000#, for the medium and heavy bombers; 600# 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. 19 Airborne rockets were still in the future.

As to armament, most of the combers in 1939 carried only .30 caliber guns, although the new YIB-174 had fittings for five .50s, and three of the seven un positions of the forthcoming XB-2/ were for .50s. Fire control systems were antiquated, however. In 1937 they had been regarded by the tactical units as "practically the same as / those of / at least ten years ago," 20 and wholly unfitted for the defensive missions of the unescarted

^{13.} MB, "Characteristics and Performance of U.S. Army Airplanes ...," 1 July 1939, sheets A and B (copy in AFINI).

^{19.} MD, "Characteristics and Performance ...," 1 July 1939

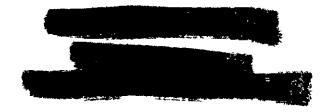
^{20. &}quot;Notes on Air Corps-Ordnance Department Conference," 15 June 1937, quoted in ATSC historical study, "Power Turrets / 1917-44/" (draft, Feb. 1945, by Lt. I. B. "ciloy), chap. 2, p. 4.



visualized
bomber, a tactical situation as early as 1933. In September 1939 neither
the B-23, the YIB-17A, nor the forthcoming B-17B and XB-24 was equipped
with turrets, while the B-18A had only a single .30 turret on top. Both
in the Air Corps and among its industrial contractors turret development
was seriously trailing England and Sermany. Fighter armament, on the other
hand, was perhaps not as critical, although the sizes and numbers of guns
were limited. To pursuit plane 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 1320 and other ground strafing planes with 6 to 10 guns is 1925. Two of the experimental pursuits
(the XP-39 and the XPM-1) mounted one and two 37-ms cannon, respectively,
but the experimental use of this weapon was at least as old as the equalderable tests of the cannon-mounted GAX in 1920 and subsequent years.

Mavigation and communications equipment in the advanced simplane models were limited in 1939 to the standard radio perpass, the marker beacon receiver, and the command and limison sets. In Airborns 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-force communications, the existence of Air Corps apathy, or other reasons. So 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, at field of research which later was to contain solutions for all-weather flying and bombing-through-overcast, 29 On the other hand, ground

^{29.} BTG 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.



^{21.} Historical study, "Power Turrets," cited above; and ND Field Service Section, "Armament and Field of Fire-Tactical and Training Airplanes / 1938-41 /," about 1941, in AAF 452.1 "Bulk", misfiled under 27 July 1938.

^{22.} The Official Suids to the Army Air Porces ..., (1944 ed.), pp. 346, 347, 351.

^{23.} ND, "Characteristics and Performance ...," 1 July 1939, sheet &; and tabulation showing armament and radio equipment for all developmental airplane models, attached to PAR, Supply Division to Col. Carl Speats, Plans Section, 9 Sept. 1939, in AAP 452.1 Airplanes, General.

^{24.} The Official Suide to the Army Air Forces ..., (1944 ed.), p. 346, 347. 25. Tabulation showing radio equipment and armament for all developmental

^{25.} Tabulation showing radio equipment and armament for all developmental airplane models, attached to HSR, Supply Division to Col. Carl Speats, Plans Section, 9 Sept. 1939, in AAF 452.1 Airplanes, General.

^{26.} See AFIHI historical study, "Radio and Radar Equipment for Air Operations, 1939-44" (draft, 1944).

^{27.} Lt. Col. Earl L. Naiden, GER Air Force, Chairman of ACTC Subcommittee on "item 9" (communications); other members represented the OCAC, the Signal Corps, and the Aircraft Tadio Laboratory at Wright Field.

^{28, &}quot;Report was" of said subcommittee, Dec. 1938, in AAF 334.8 "Bulk".

equipment for enemy aircraft warning did exist: the JCR-268 detector, which had been developed by the Signal Corps primarily for gun laying 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. 30 Im September the Air Board called for an "adequate" mircraft warning service, and by December 1937 the Air Corps and the General Staff were planning a 32 new Air Defense Command to employ detectors in a constal warning service.

The equipment for air defense was definitely inferior, however, to the best European devices, especially the British CR equipment (range, 185 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 33 was America's inferior position to be fully appreciated in the Army 34 and energetic steps taken to embark on a comprehensive radar development program.

Compered with the critical status of air defense aids, the guided missiles situation was not as serious nor as urgent a problem in 1939. The idea of remote-controlled macrial torpedoes and bilotless 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. Lettering 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, 35 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 wissile. 36 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. 37 More practical, in terms of sconomy and immediate tactical use, had been the related radio-controlled pilotless airplane for target use in gunnery training.

31. Air Board report, 15 Sept. 1939, tab C, p. 3, in 4. J. Lyon project record book no. 15-4.

34. Hemorandum for Maj. Gen. H. H. Arnold, DC/S for Air, by Brig. Gen. G. H. Brett, "The Assistant," 13 Dec. 1940, in <u>ibid</u>.

^{30.} The SCR-269 was first deponstrated in May 1937, and the SCR-270 (two models), in Nov. 1939. / Annual / Report of Chief Signal Officer, pp. 219, 220, quoted in Joseph Reither, "Communications Techniques in the AAF" (AAF Historical Studies No.), draft, p.

^{32.} Col. Carl Spantz, "Notebook" (Nov. 1939-March 1940): 27 Dec. 1939, meeting with "Gen. Strong's Office" (NDGS); and 12 Feb. 1940, assignment of Maj. S. P. Saville to Gen. Chaney's new air Defense Command. In AAF "Bulk" files.

^{33.} The mission included Lt. Col. (?) A. W. Marriner and others. After its report of about 1 Dec. 1940, a "full-dress" meeting was held between the Air Corps, the Signal Corps, the May, and the new MDRC 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 676.3 Wireless—Radio System.

^{35.} Air Corps Board report no. 9, 25 Oct. 1935, pp. 3-4, quoted "Radio and Radar Equipment for Air Operations, 1939-1944," (AAF Historical Studies, No.), draft, p. 57.

^{36.} Ibid.

^{37.} Materiel Division, Annual Report. Fiscal Year 1930, p. 51.



The Army had completed its first successful test of such a target plane in 1934, when radio controls and Autometic Flight Control Equipment were sufficiently advanced to make the project workable. 38

Military Requirements and Strategic Heeds, 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 linkeritance of ideas and partially completed experiments from the years of peace between 1913 and 1939, covering the whole range of combat simplenes, power plants and propellers, ordnance and radio equipment, and guided missiles. Furthermore, itsestrategic needs were being carefully formulated.

In terms of strategic and tactical needs, the Trum Board's wair plan for the defense of the United States" of 1933 Iwas still valid, as far as the areas of operation were concerned. This Board had visualized the Army air arm as serving in its customery roles of bombardment, pursuit, transport, and recommaissance, all toward the goals of achieving air supremacy, lending 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 longrange reconnaissance, "demolition" of the energy'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 Vestern Hemisphere, and five areas corresponding to the overseas possessions of the United States. The war plans used by the Drum Board were the "Red" (Pritish Empire), the "Grange" (Japanese Empire), and the "Red-Orange" plan, hich assumed "a coalition . . . with Japan." 2 In the latter plan, considered the most likely, Japan wo ld merely be "contained," while "full nower" was exerted against "Red." The Joviet Union and China were re-arded as either neutral or friendly to the United States, while Germany (in the first year of Wasi 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" mirplane (which became the IB-17 in 1935) and the IB-15 long range bomber (to be delivered in 1937). By 1939 the seven strategic areas of 1930 sers atill valid, and were re-expressed by the Air Board in September 1939. 4 The potential enemy, however, had shifted

^{38.} AFI'll historical study, "Radio and Radar squipment for Air Operations, 193 >-1944" (draft, 1944), Chap. V.

^{1. &}quot;Report of Special Committee, General Council, on Employment of Army Air Corps under Certain Strategie Plans," 23 pp., approved 11 Oct. 1933, in AAF 334.7 "Bulk" files.

^{2.} The latter wording is quoted from memorandum by C/AS on "Air plan . . .," 27 July 1933 (27 pp.), which was exhibit I in the Drum Board report; but the Board echoed ruch the same opinion in its own report.

^{3.} Another interpretation, that the XB-17 was designed instead for a Pacific war, with Japan a more likely enemy than Jermany "in 1935," is given in another AFIHI historical study, "Review of Aerial Barfare for the Scientific Advisory Poard / groups /," Jan. 1945, p. 6.

^{4.} The Air Board was appointed 23 March 1939, and its report approved by the 13 (that is, the General Staff and the S/N) on 15 Sept. 1939. See its report, AG 320.2 (6-26-39), 15 Sept. 1939, p. 1, in A.J. Lyon project record book no. 15-A.

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 1933 were still valid, as they were restated in Sentember 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. 5 The new political situation was too obvious to mention in the Board's directive. Instead, the immediate problem of military requirements, as nosed in General Arnold's directive, was to prepare a program for catching up with the admittedly-superior foreign progress. O Its report of recommendations, 28 June 1939, represented the views of OCAC Headquarters, of the tactical air arm, and of the materiel center, and consisted of a comprehensive set of proposed military characteristics for combat airplanes, related weapons and equipment, and trainer and ground-are 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 sonly be determined during design and construction by engineering calculations, and wind tunnel and flight tests." To substitute preconceived, detailed characteristics for broad onjectives would "restrict the technical staffs at Wright Field and the alrerage 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

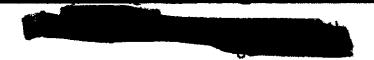
^{8.} Kilner Board report (above), especially pp. 5, 9, 12-14, 10.



^{5. &}quot;Final Report of Air Corps Board [Kilner Board] on Revision to the 5-Year Experimental Program, 28 June 1939, and appendixes, in A. J. Lyon project record book no. 13.

^{6.} Memorandum for President, Research Board (General Kilner), by Maj. Gen.

H. H. Arnold, C/AC, 10 May 1939, in ibid., exhibit A.
7. Brig. Gen. W. G. Kilner, AC, and Col. Charles A. Lindbergh, AC Reserve, both attached to OCAC; Lt. Col. Carl Spaatz, Plans Section, OCAC; Lt. Col. Earl L. Maiden, GHQ Air Force; and Maj. A. J. Lyon, Materiel Division, Wright Field.



Among the advanced ideas brewing in the Air Corps in 1939, the following could be translated into combat material 9 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 bember, 2-engine: 2,667 mile range (1000 mile radius); 400 mph; 30,000 lbs; normal bomb load, 500 lb.

Light bomber, 2-engine: 800 mile range (300 mile radius); 400 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 c mpact engine installation.

Equines: 1,300-2,400 in 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. juided 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 power plants could not yet be foreseen. As to guided missiles, General Arnold had presented a Wright Field study asking for \$960,000 for "special projects," including the "application of pasic research . . ., aerial targets, aerial torpedo, etc.",10 but the Kilner Roard did not specifically include the problem in its recommendations. Radio recommendations for the new bombers and pursuits were limited to the standard communications sets and to navigation aids "for effective day-andnight 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 producement "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 Marfare Service, the Corps of Engineers, and the Quartermaster Corps.

10. Staff study by Materiel Division, no date, p. 6, in Kilner Board Report, Appendix I.



^{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 Kilner Board report, tabs G through O.



By September 1939 the Kilner Board program had been revised downward, In connection with the immediate budget problem for the fiscal year 1941. The 3000-mile long range bomber had been deleted (but was to be revived later in the IB-35 and the IB-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 air-plane itself."

The Air Corps Experimental Establishment, 1919-1939

The laboratories, special hangers, 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 Materiel Division was transferred to that location from nearby NeCook 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, Fower 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, \$544,343 was spent for machinery, and laboratory apparatus, and \$199,331 for general maintenance and improvement; and \$6,481,000 was cormarked for the construction of additional laboratories and other fixed equipment. " The Air Corps was skillful in impressing public opinion with it "meronautical 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 (4,300 rpm) generated by a 6,000 hp motor, a motor more powerful than any locomotive engine and three times more powerful than any sircraft engine. Among other equipment were engine test stands, static test

11. Mentioned in memorandum for Materiel Division by C/AC, 29 Aug. 1939, in A. J. Lyon project record book no. 13.

12. War Dept., "Research and Development Program, Piscal 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 A. J. Lyon book no. 15-A), which, with WDGS and 3/W 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 Slectronics was ultimately approved, in terms of Signal Corps—Air Corps administrative 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. Mary Air Forces Research and Development Program," no date, about

ipri 1944, 19 pp., in MAS file "700.430, Kilgore Committee-Office of Technological Mobilization."

Air Gorps Section of "War Department Research and Development Program, Fiscal Year 1940," 23 May 1939, in AAF 400,112 Test, Development Work. Sectore the war the Air Gorps had opened many areas of Wright Pield 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 carlier

equipment, a 40,000-feet altitude pressure tank, and a high-altitude plane (the XC-35) pressurized at 35,000 feet. 4 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 1,984, 1,759 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. Perhips historically this was just as significant as the later, more-widely publicised appearance of cigilians in the strategic and tactical councils of the army in World War_II. 7 lt was a common observation within the Air Corps that "the [Materiel] Division is run by a let 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 isportant 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 <u>Directory of Inspection Services and Testing Laboratories of the Federal Government</u> (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 Aeronautics 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 40 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. &}quot;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 their 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, an' the Chief of the Air Corps in Way 1939 had asked the Kilner Board to recommer " " ore civilians for research and development. 10 Other more serious problems than numbers existed. A Wright Field survey in January 1930 11 had urged that its experimental personnel must constitute "a cross section of Air Corps officer personnel and civilian engineers, clark; mechanies, 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. 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 retrenchment 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 permament 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

9. Opinion of the Federal Aviation Commission (Nowell Commission), in its Report, Jan. 1935, pp. 154-155.

11. "Special Personnel Study on Givlian Personnel of the Materiel Division ..."
by Capt. C. S. Irvine. 22 Jan. 1939, in AAF 321.1 "Bulk" files.

^{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 1,759 to 2,478 civilians. See Materiel Command Historical Office, Mistory of the Materiel Command, 1926-1941, p. 6a.

^{12.} Toid., p. 15.

^{13.} Ibid., p. 12.

^{14.} Ibid., p. 13.

^{15.} In addition, after the Chief of the Material 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 surgested, was to withdraw the 15 Wright Field officers at the AC Tactical School at Maxwell Field, and discontinue the School entirely. R&R, Brett to C/AC, 13 Way 1940, in AAF 321.9 Material Division (U).



were only one pursuit and one boxbardment project officer, each with one civilian assistant, each handling three or four projects, making it impossible to enduct adequate visits to the plants and adequate operations and planning at the field. If again, a permanent nucleus of officers was indicated—a program that also had had the support, earlier of the Howell Commission. 17

diabling of the enrollment at the dir Corps engineering School at dight Field, 15 and a triple increase in the assignment of officers as post-graduate students in university originaring departments. 17 Advanced university training for engineering officers had until recently—seen virtually non-existent for years, nor had a program been recommended by the fowell Commission in 1935. 20 The for Department had authority enough—sore than that of any other Federal argray 21—to expand this training program, including enabling legislation in highest to be detailed to such institutions. 2 The Air Corps, furthermore, had been given special authorizations, including an act of May 1920 permitting as rany as 25 officers to be trained in seconsulted engineering at a time, and an all-inclusive provision in the Air Corps expansion act of 3 April 1939, permitting post-graduate training faithout reference to any / earlier statutory / limitation. 2 In terms of actual enrollment, Eright Field had sent

16. "Special Personnel Study..." (cited earlier), pp. 9, 11-12.

17. Jes its Report, Jan. 1935, op. 154-155. Both officers and civilians were included in the occasion's idea of a "Corps of Association! Engineers."

13. The AC Argineering School was the Army's center for the training of AC officers primarily for material development and production. One other Army school devoted to enterial matters, the Army Industrial College established about 1920, was interested primarily in industrial planning, production, and contracts on an Army-wide scale.

19. "Special Personnel Study ..." (cited earlier), pp. 4, 12.

20. The Federal Aviation Commission (Howell Commission), while it spoke broadly in favor of a "comps of acromatical 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 Jerone C. Humsker, then head of the M. I. T. nechanical engineering department.

21. Since 1926 no Federal spency overt the Wer Perertment (whose legislative authority is cited below) had been permitted by the Comptroller deneral to send Government employees to technical and other civilian educational institutions. See the letter's ruling of 7 July 1926, copied in Mational Resources Committee, Pelation of the Federal Government to Perserch (1939), n. 37.

22. Acts f 30 June 1976, 39 Stat. 166; 4 June 1920, 41 Stat. 786; amendment of 3 June 1926, 44 Stat. 705; all contained in U. S. Code, 10:535. See also later, broader energhents, 13 Yer 1041 (55 Stat. 109) and 38 June 1941 (55 Stat. 369), in ibid. An act of 6 Peb. 1942 (56 Stat. 50) removed any percentage limitations on any branch of the krey and on any of the personnel categories—Regular Army, Army of the U. 3., and enlisted men.

23. Act of 10 May 1920, 41 Stat. 594, in <u>C. S. Code</u>, 10:298; and Act of 3 April 1939, 53 Stat. 556, sec. 2.



three officers to Nichigan, C. I. T., and Stanford in September 1938 to study aeronautical engineering, and four officers to C. I. T., Stanford, and M. I. T. in September 1939 24-one more but hardly the triple increase resonmended by the survey earlier in the year. In both of these enrollments, Wright Field and OCAG headquarters were apparently operating under the 2% rule rather than under the broader legislation of May 1920 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 mirphanes and weapons, they were the indispendable 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 budgets of other governmental laboratories, of industry, and of universities engaged in peacetime research, Air Corps funds were actually quite substantial. The fonds specifically earmarked for "research and development" were as follows:

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

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

	1937	1938
Air Corps	7.1%	5.4%
Navy Bureau of Aeronauties	4.1%	5.1%
Mational Bureau of Standards	4.1%	5.1% 2.5%

^{24.} Memorandum for AG by C/AC, 1 March 1938; and Exec., MD, to OCAC 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 works 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 OCAC Personnel Division was still invoking the 2% rule. (See R&R, Personnel Division to MD, 12 April 1940, in AAF 210.66 Detail to Divilian Educational Institution: (U)). The 1939 surollment was 2.7% of Wright Field's efficer strength of 149 (as of 1 July 1939). The statuses of 1916, 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.

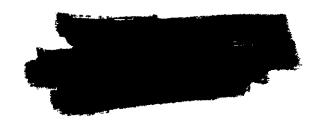
^{27.} For example, the AC research budget in 1937 was \$4,518,460 (see tabulation below), which compares with the estimated research expenditures (in the physical and natural sciences) as follows: all Federal laboratories and experimental stations, \$124,000,000; all industrial laboratories, \$100,000, 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 Research (1939), pp. 3, 8, 65, 67, 130. Compared with the Navy and other Federal laboratories, the Air Corps stood



Air Corps Appropriations for Experimentation, nesearch, and Development, 1920 - 1940 23

liscal Year	Micesearch and Development*29	Civellan Payroll	"Service Test" 31	Total Research Appropriation
1920				4,522,073
1921				5,928,062
1922				4,175,545
1923				3,150,517
1924	1,130,600	1,320,000		3,000,000
1925	1,190,000	1,490,398		3,080,898
1926	900 , 000	1,730,000		2,630,000
1927	702,720	1,41,280		2,184,000
1,923	750,000	1,450,000		2,200,000
1929	624,550	1,569,090		2,263,640
1930	675,930	1,530,000		2,255,930
1931	675,930	1,623,331		2,299,261
1932	644,599	1,648,238		2,299,397
1933	1,153,967	1,667,600	375,000	3,196,567
1934	1,566,797	1,296,020	151,000	3,013,817
1935	1,924,984	1,561,315	310,000	3,796, 79 9
1936	3,968,563	1,648,238	350,000	5,966,851
1937	2,468,900	1,657,060	392,500	4,518,460
1938	2,929,135	1,104,950	316,805	4,349,890
1939	?,CA3,A09	1,201,550	329,331	3,574,290
1940	3,037,962	1,5শঠ,83৪	233,200	10,000,000

^{31.} Known aloc as "Project 73."



^{23.} Adopted from work sheets and tobulations in NSS, including: WF to AC/S (F), wG Mqs, teletype, no date, about 6 Feb. 1943; and date from Baker Board report, 1934; all filed in MkS "705.430 Kilgore Committee--Office of Technological Mobilization."

^{2).} Known also in early years as "Experimental Procurement" and later as "Froject 71."

^{30.} Known also as *Project 72.*

These annual sums are in general a conservative understatement of woney 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 specialised facilities, 32 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 m 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. 34 Historically compared, 1920 to 1940, the research budgets showed still other trands: that the research budgets of the immediate postwar years of 1920, 1921, and 1922 were substantial; that they were not matched b comparably high budgets until 1936; and that during the interwening meager years 1923-1935, appropriations reached their lowest figure in1927, 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 kir 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, had tended to hide some of their research funds under other headings as "window dressing," in order to avoid the popular stigms attached to Federal research activities. See National Resources Committee, Relation of the Federal Government to Research, (1939), pp. 63, 87, 88.

34. See tabulation of Air Corps appropriations, 1926-1939, in "Legislation Relating to the AAF Material Program, 1939-1944" (AAF Historical Studies No. 22, Nov. 1944), p. 161.

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 BudgetBureau, the Congress, an apathetic or hostile public opinion, or an ineffective public relations volicy 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.

Superisposed on Wright Field's resources for development and research was an administrative and military hierarchy which controlled and supervised empenditures; 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 36 and the subsequent Army Regulations, 37 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. 38 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 materiel 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.

^{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.



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

^{37.} AR 850-25, governing "Development ...of / Army / Equipment," various editions (15 July 1931, 23 July 1936, and 30 June 1943); and AR 95-15, 21 April 1930, 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 OCAC 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).

Immediately supervicing the nine laboratory branches at Wright Field in 1930 was the Chief of the Experimental Engineering Section, Major Franklin O. Carroll, and his Technical Staff. This "EES," 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 rajor 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. G. 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 materiel problems such as production and industrial mobilization. Wright Field had ever since 1926 been without direct representation in the inner councils of OCAC Headquarters. The small "Materiel Liaison Section" in Washington had actually been a part of the Supply Division. It had had no rank or prestige comparable to the other basic Air Gorps functions of Trairing, Personnel, and Operations, and it had been abolished about September 1933. Now in October 1939, after some opposition in Washington, 42 the Chief of the Lateriel Division moved to Washington, together with a small staff of

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's, Memorandum for C/AC by Brett, 13 Sept. 1939, in AAF 321.9 Materiel

Division (U).

^{29.} See Nateriel Command Historical Office, "History of the Materiel Command, 1926-1941.2 For drafts of proposal for a Material Division in 1926, see AAF 321.9 Materiel Division (U). Previously, the Engineering Division at McGook 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 Mar 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 C/AC by Col. C. G. Hall, Chief, Supply Division, in 191d.

^{40.} Materiel Division, L. I. (letter of Instructi) No. 1, 2 Oct. 1939; copy in Materiel Command Historical Office, "History of the Hateriel Command, 1926-1941," pp. 38b, 38c. The move was announced by a press release in Sept. 1939.

^{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 off-and-on had a single representative in Washington-Capt. R. L. Walsh in 1926.

Memorandum for Exec., OCAC 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, WF (U).

42. The Supply Division had opposed, while Plans and others favored the move. See "Organization of the Army Air Arm, 1935-1943" (AAF Historical Studies No. 10, 1944), pp. 75, 76. The move apparently also had General Arnold's support. Brett at Wright Field favored the move only if he 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

planning officers includin. Major A. J. Lyon, Capt. B. W. Chidlaw, and Capt. J. F. Phillips (Maj. B. E. Meyers came to Mashington later); and left his Assistant Chief, the Technical Executive, and the bulk of the technical and laboratory staffs at Nright 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

	<u>Washington</u>	Wright Field
Oct. 1926	Material Division Limison Section (abolished about Sept. 1938)	<u>Kateriel Division (MD)</u> including <u>Experimental</u> <u>Engineering Section</u> , (EES), with 6 type branches or laboratories
May 1937 to March 1939	Sane	Same Except develorment and production sections combined into a simple Engineering Section
April-Sent. 1939		Same Lxcapt Experimental Engine- ering Section restored, and Technical Steff and 2 addition- 1 1 boratories estephished
2 Get. 1939	Chief, Esteriel Division (moved to Washington, in- cludin a staff section for Experimental Francering)	Assistant Chief, Nateriel Div. Including fecunical Staff, experimental Includering Section, and 9 type laboratories
Dec. 1941	Same, except Chief also desi- grated as <u>Assistant for</u> <u>Procurement Services</u>	Same Except Technical Staff placed within EES
9 March 19/2	Same, except redesi mated <u>Nateriel Command</u> , Including a <u>Chief of Staff</u> - <u>Experimental</u> (C/S-E)	Some, excent redesignated Material Center
29 March 1943	Same, except redesignated AC/AS Lateriel, Maintenance and Distribution, Lateriel Division, Development Engineering Branch	Same, except redesi nated Nateriel Command, Engineering Division
17 July 1944	់ដ េ ខ	Same, except redesignated Director of Tateriel and Services, Material Command, Laringering Division
19 July 1944	Same, except redesignated AC. AC. Materiel and Services. Materiel Division	
31 Aug. 1944	Same	Same, except redesignated <u>lir</u> <u>Technical Service Compand</u> , <u>Engineering and Procurement</u> <u>Division</u> , and laboratories reorganized under 5 branches.
November 1044	Same, except <u>Materiel Division,</u> <u>Engineering branch</u> , and <u>Research Liaison Branch</u>	

In terms of the concepts of "centralization" and "decentralization," the Materiel Division had been completely decentralized since 1926, and only slightly less so after 2 Detober 1939. The later, widely-publicized decentralizations that were to accompany the general AAF reorganizations of 20 June 1941, ? Merch 1942, and? Merch 1943 had only a slight effect on research and development policy and control. Fright Field activities continued, thether they were called the Materiel Division, the Materiel Center, the Materiel Command, or the Air Technical Service Command, while the staff office in Washington likewise mercly underwent various changes in name, with, lowever, essentially the same leadership, the same nucleus of key officers and civilians, and the same channels over the whole period 1939-1945. 43

Such a schematization of the history of the Air Dorps research and developer it organization (as above) is of on rise 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 1937. There were also minor internal reorganisations 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 charges in research and develorment collicies, especially collicies as to military and strateric requirements, testing and proving procedures, industrial and university research projects, relations with other Federal research a mincies, and exchange of technical information with the Allies. It is sufficient here to outline some of the other agencies that existed in 1937 within the Air Corps and the Har Department with staff functions that home on research and development noticy. Wright Field and the Meteriel Division alone did not costrol policy. For example, the Field's representative on the Kilner Board in Nay-June 1939 (Maj. A. J. Lyon) had been the lowest ranking officer on the Board. Other policy agencies in OCAC Readquerters were the following, listed in general according to echelon:

Secretary of War

AC/M (when contracts were involved)

Coneral Staff
Chief and Debuty Chief of Staff

4C/S - U-4 (withdrawn from chain of command about 1941)

Budget Division (when research budgets were involved)

Air Corps Technical Committee (usually representing OCAC, GM) AP,
and DUS; the Materiel Pivision supplied the Recorder after Dept.

1039)

A3. Taker, especially in 1944 and 1945, as the war progressed, staff officers in Bashington were more and note assimed to overseas duty, such as Chidlaw in 1944, but many of the lay personnel in AC/AS, MSS have remained.

Office of the Chief of the Air Corps
Chief of the Air Corps
OCAC Executive
Plans Section
Supply Division (concerned more with production than with research in July-August 1939)

Orlhance Department Chemical Warfare Service Signal Corps Quartermaster Corps Corps of Engineers and their respective interservice "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 presearchess, Congressional pressures on behalf of ideas of inventions of constituents, military attache and other observer rissions abroad, special boards like the kilner Board, and a host of their 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 a reneits 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.

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The Scientific Potential for Air Supressey, 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 Mavy, 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 programs of wide scope but primarily devoted to the task of insuring our military supremacy."

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 secame 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, Bunnen burners, and bespectacled and bewhiskered 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 application 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 Mazi Germany was usually cited as the worst example of the use of science for antisocial goals. Mymptometic of this confidence in peacetime science, coupled with an apathy if not bostility to war research, was the survey of America's scientific resources in 1937-1940 by the Mational Resources Committee. Its directives in 1937 and 1938 and its recommendations in 1938 and 1940 were all stated in terms of national prosperity, mational welfare, and the improvement of standards of living,

^{3.} Science News Letter, 1939, passin, and J. D. Bernal, The Social Function of Science (London, 1939).



ESRR No. 50-461-351, 18 Aug. 1939. "Future Aeronautical Research Froblems." prepared by M. Ketcher, Technical Staff; in MAS file on "FY 1941 NAD Program."

^{2.} See J. D. Bernal, The Social Function of Science (London, 1939),
3. Science Year Letter 1939 program: and J. D. Barnal. The Social

all without specific reference to the war potential existing in America's laboratories. Scientists had, of course, some a long way even to support social objectives such as the "matiemal 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 vespons of war. America on the eve of the European war was spending over one half of 15 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 sconomic framework, the annual expenditures for research in the physical and natural sciences were estimated somewhat as follows:

Federal laboratories and agencies \$120,000,000
Industrial laboratories 100,000,000
University and college laboratories 51,000,000
Endoved foundations 3,000,000

4. National Resources Committee, Research & National Resource:

Yol. I. Relation of the Federal Government to Research (Cot. 1938, 255 pp., published as H. Doc. No. 122, 75 Cong., 1 sess., 1939); and yol. 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, andorsing 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. 111).

5. Estimates by J. D. Bernal, British physicist, in The Social Function of Science (London, 1939), pp. 64-65.

6. National Resources Committee, Relation of the Tederal Government to Research (1939), pp. 5, 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 1918-37.

Furthermore, it was estimated that of these research expenditures, 25% 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 mational resources for improving its weapons for war.

Sovernment 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 impulse 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 procedessor agencies in the Commerce Department, which, as the regulatory body for civil aviation, controlled air worthiness requirements of commercial planes (that is, landing and take-off performance, mirplane controls, and stability) by means of technical inspection and licenses; (2) the Air Corps itself (described earlier) and the Mavy's Eureou 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 shead of the existing state of the art, as based on the tactical needs of the services"; and (3) the Mational Advisory Committee for Aeronautics and its laboratories and facilities, through which the Government provided basic, indispensable accentific knowledge on aeronautical problems common to commercial and military mirplanes, in effect a substantial subsidy for basic seronautical research, whether for peacetime or wartime use.

I. Views of Jerome C. Hunsaker (H.I.T., and a member of the MACA), in his Nation-wide appraisal of zeronautical research resources, 1940, in National Resources Planning Board, ___Industrial Research (1941), pp. 127-143.

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

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The NACA has been broadly enough publicized, at least as well publicized as Wright Field, not to varrant 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" with Wright Field. The NACA's main sphere of sciivity--"scientific research on the fundamental problems of flights--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 serodynamics, structures, propulsion, and materials:

The Committee conducts scientific laboratory and free-flight research in the broad field of serodynamic 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, HACA appropriations for research, laboratory construction at Langley Field, and other activities totalled \$4,063,980, of which \$1,708,430 had been obligated during the fiscal year. These sums

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

^{3.} The NAGA 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.

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

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

^{6.} Regular 1939 appropriation (23 May 1938), \$1,700,000, plus Supplemental (2 May 1939), \$2,363,980, totalled \$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 Egyport, 1939, p. 46.

corresponded with expenditures in previous years as follows:

Expenditures of the MACA, 1919-1939

Fiscal Year	Total Impanditures	Payroll and other Parsonal Services	Facilities and Equipment
1919	\$ 204,381	\$ 65,657	\$ 83,447
1920	174, 296	88,859	17,879
1921	199,959	100,836	17,619
1922	193, 559	101,595	15, 226
1925	209,591	95,532	41,784
1924	269,593	185,008	25,991
1925	437 .510	270,191	96,313
1926	516,709	302,648	127,596
1927	491,920	341,574	62, 765
1926	529,144	387,372	51,495
1929	611,633	448,771	57,589
1930	1,477,984	532, 265	832,879
1931	1,173,014	617,731	425,842
1932	959,518	670,858	157,018
1933	827,186	500,043	99,426
1934	690,240	581,846	28, 264
1935	747,827	616,208	33,914
19 36	1,157,746	775,114	177,751
1937	2,337,638	928,337	1,200,262
1938	1,918,868	967,571	660,536
1939	1,708,430	1,065,812	398, 266

In terms of facilities, the MACA in 1939 had a modest staff of 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 MACA in World War I by the War Department? Its buildings and equipment, which were more

^{7.} Based on NACA, 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 NACA (telephone conversation with Nr. Shaw, NACA, 2 Narch 1945).

^{8. 54} of them were in Washington. Figures from NACA resonnel Office, received by telephone 28 March 1945.

^{9.} The MACA, when it was given the space in 1916, 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 neronautics. Seen, however, the Navy moved to the other side of Cheenpeake Bay, while the Army moved to McCook Field, in 1917. MACA Annual Report, 1919, p. 13.

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impressive, included the following: 10

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 veriable-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 73 x 3-foot refrigerated wind tunnel 12-foot free-flight wind turnel 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 etability 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) was about to be built at Moffett Field, Sunnywale, Calif., after a legislative history of almost a year including the original formal proposal by the MACA in December 1938. The blessing of the White House in February 1939, and a 6-months struggle in Congress leading to the act of 9 August 1939. With this new laboratory, the MACA was able to double its capacity for research.

^{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 Materiel Program, 1939-1944" (AAF Ristorical Studies No. 22, Nov. 1944), pp. 105-114.



^{10.} MACA Amnual Report, 1939 (dated 16 Nov. 1939), p. 38.

^{11.} Named in honor of Dr. Jeseph S. Ames, who retired from the chairmanship of MACA in October 1939. See MACA Annual Report. 1939. pp. 3-4.

^{12.} Maj. Sen. Occar Vestover, C/AC, on 19 Aug. 1938 had recommended to the MACA that a second laboratory be built somewhere in the interior or on the West Coast, to relieve "the congested bottle neck of Langley Field." For details on the selection of the site, see MACA, Annual Report. 1939, pp. 38-39.

Although appropriations were apparently no more easily obtained by the NACA than by the Air Gorps 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"; 14 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; 15 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. *16

The Air Corps in 1939, as always, regarded the MACA as its chief resource for basic aeronautical research. Legally the MACA existed for common use by all sources—public and private—who wished to "hire" its "community services," so to speak, of wind tunnels and other facilities. This theory was modified in actual practice, in that the Air Corps and the Mavy Bureau of Aeronautics—rather than either the university or industry members of the Committeen tended to exercise centrol 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 MACA'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 peace-time problems in 1939, nevertheless in total war they were convertible

15. Report of the Federal Aviation Commission, Jan. 1935, p. 227.

16. National Resources Committee, Relation of the Federal Government

to Research (1939), pp. 28-29.

^{14.} Baker Board, Report, July 1934, p. 18.

^{17.} The Federal Aviation (Howell) Commission (in its Report, Jan. 1938, p. 225) 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 Fortuma 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 smong the many procurement agencies of the Government. For example, there existed a comprehensive Directory of Inspection Services and Testing Laboratories of the Tederal Government, compiled a few years carlier (1935) by the Treasury Department's Procurement Division and the National Bureau of Standards. Taken together, Government laboratories were expending about 125 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 Ordmance Department, and the Signal Corps Aircraft Radio Laboratory, all of whom were working on Air Corps projects in 1939. Nost 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 Bursau 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. Ropkins) 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 Besources 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 Mation-wide inventories and surveys of industrial research were available. Among them the most comprehensive colons was one

^{18.} Memorandum for AS/W by C/AC, 17 April 1939, in AAF 400,112 Tests and Experiments (U).

^{1.} Among the other surveys, besides those discussed below, were the fellowing: (1) an inventory by the Mational Bureau of Standards, published in July 1936 as a Directory of Connercial Testing and College Research Laboratories in Universities and Industrial Concerns (MBS publication M. 125). This directory, which covered also university research, had also been issued in earlier editions, in 1927 (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 H. 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 (118 pp.).

made by the Mational Research Council in 1938, continuing a periodical practice going back to 1920. It was based on a questionneire eddressed to industry, and published as a directory of Industrial Pessarch Laboratories of the United States. 2 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 1.769 laboratories listed -- a ready reference for research planning officers. The BRC survey was examined statistically and critically in 1939-1940 by two other Federal agencies, the fork Projects Administration and s sub-committee of the Mational Resources Committee. Among the trends in 1939 shown by these surveys were the growth of research leboratories as a phase of industrial expension. Over 1,750 corporations in 1938 had research facilities collectively totalling 2,237 leboratories and 44,292 research personnel. This compared with England's 435 or more laboratories, and represented a 10-fold expansion since World 'ar I somewhat as follows:

2. Fublished 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 inclusive, published as NRC <u>Bulletins</u> 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 Vorld Var I and World War II. A later (7th) edition was also published as NRC <u>Bulletin</u> No. 104 (Dec. 1940).

5. These evaluations were published in: George Perazich and Philip M. Field, Industrial Research and Changing Technology (Work Projects Administration, Mational Research Project, Peport No. 1940, 81 pp.); and Franklin S. Cooper, "Location and Extent of Industrial Research Activity in the United States," in National Resources Planning Board (successor to National Resources Committee), Research—A Mational Resource: II. Industrial Research (Washington, 1941, 370 pp.), pp. 173-187.

4. Estimate by J. D. Bernal in The Social Function of Science (London, 1939), pp. 107-108. In another place (p. 56) his estimate is 30° to 600 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 12 declined to give their personnel strength.

Growth of Industrial Laboratories and Research Personnel 5 in the United States, 1920 - 1940

	t tunber f		Number ' Number ' Total of ' of ' Resear		Total Research	t	Percentage of Personnel			
	f Companies	, ,	Companies Reporting		Labora- tories	1	Personnel Reported ⁶	l t	Fall-	Part- time
1920	297	*	265	1	307	1	7,367	1		
1921	526	1	462	1	total till	1	9,350	ľ	73,6	26.4
1927	999	•	926	•	1,147	1	15,982	•	74,5	25,5
1931	1,620	1	1,520	•	1,926	:	32,830	•	87.9	12.1
1933	1,562	•	1,462	;	1,854	1	27,567	•	89.7	10.3
1938	1 1,769	1	1,722	!	2,237	1	44,292	•	97.4	2.6
1940	2,254	1	2,350	ŧ	3,480	1	70,033	•	!	المنيينيية

5. Based, except for data for 1940, on George Perasich and Philip M. Field,
Industrial Research and Changing Technology (Work Projects Administration,
National Research Project, Report No. M-4, Jan. 1940), pp. 63, 64, 65
(parts of tables A-1, A-2, and A-4).

5. 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. (<u>Ibid.</u>, p. 57).

7. National Research Council, Industrial Research Laboratories of the United States, Including Consulting Research Laboratories (7th ed., Washington, Dec. 1940, 373 pp.), p. 11,

8. Franklin S. Cooper, "Location and Extent of Industrial Research Activity in the United States," in National Resources Planning Board, Research — A National Resource: II. Industrial Research (Washington, 1941, 370 pp.), pp. 173, 176.

9. Another estimate, by Villiam A. Hamor of the Mellon Institute, was 25,000 in 1937. See Mational Resources Committee, Relation of the Federal Government to Research (1939), p. 8,

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 L 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 12 Personnel, 1921 - 1938

	f Over-all sample of Commanies 18								
Occupation	1921	1 1927 1	1931 1		1938				
Number of companies sampled	21.6	1 561 1	1,132	1,132	1,224				
Humber of research workers	2,358	16,765	15,057	13,090	19,797				
Percent of research workers	100.0	100.0	100.0	100-0	100.0				
Director	7.8	1 5.2 1	5.6	5,3	4.1				
Ingineer	1 15.5	1 15.9 1	21.3	20,1	23.2				
Chemist	1 33.3	27.2			28.5				
Physicist	1.3	2.3	2.1	1,5	3.5				
Metallurgist	1,1	1.2	2.2		3.3				
1	t				1				
Other professional workers	14.1	* 10.9 *	9.4	10.2	8.5				
Laboratory assistant	19.6	25.0	18.4						
All others	5.7	11.1 1	14.6	13.8	11,4				
Unspecified	0.6	0.2		0.8	0,4				

^{10.} J. D. Bernal, The Social Function of Science (London, 1939), p. 60.

1. Ibid., p. 56.

^{12.} Based on tabulations published in George Perssich and Philip M. Field, Industrial Research and Changing Technology. (Work Projects Administration, Mational Research Project, Report No. M-4, Jan. 1940), p. 78, table A-19.

^{13.} Representative sample varying between 60 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 <u>ibid</u>.

Industrial research in America, like production and distribution, was concentrated in large firms. Half of the research personnel in industry in 1938 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 Hakelite 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. Lastman Lodak Company Miectric Auto-Lite Company Firestone fire and Bubber Company Ford Motor Company General Electric Company General Motors Research Corporation General Motors Truck and Coach Company: Tellow Truck and Coach Manufacturing Company Goodrich, B. F., Company Goodyear Tire and Rubber townsay, Inc. Gulf Research and Development Corporation Hercules Powder Company Hudson Notor Car Company Humble Oil and Refining Company International Harvester Company Linds Air Products Company Monsanto Chemical Company Fennsylvania Railroad Company Philes 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.

^{14.} George Perssich and Philip M. Field, Industrial Research and Changing Technology (Mork Projects Administration, National Research Project Report No. M-4, Jan. 1940), p. 68.

Standard Oil Company (Indiana)
Standard Oil Company of California
Standard Oil Company of Louisiana
Standard Oil Development Company
Sun Oil Company
United Show 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.

As to this concentration of research in large firms, the issue of large vg. small corporations for seronautical development was apparently not a significant one in the Air Gorps in 1939. In 1935, however, the Federal Aviation (Howell) Commission had favored a few large sircraft 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. 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 alcos 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.

15. Science News Letter, 28 Oct. 1939, n. 280. In 1940 the Air Corps research budget rose sharply, from 3.5 to 10 millions.

17. Subcommittee (Kilgore) en Technological Mobilisation, Senate Committee on Military Affairs, Hearings... S. 2721, Oct. - Dec. 1942, especially pp. 215-216, 285, 380-475; and J. D. Bermal, The Social Function of

Science (London, 1939), pp. 143, 152-153.

^{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 memases to the development of good military aircraft." (p. 151-162).

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Whether the Air Corps Nateriel Division knew of these particular national scientific surveys and were using them in 1939-40, in the early months preceding national mobilisation, 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 sirplanes and aeronautical equipment. The sircraft and allied industries -- rather than Wright Field or the universities or even MACA-were and had been ever since before World War I the Army's basic source for applied research and experimentation leading up to new materiel. Although a few important simplanes 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-5 out of 10 millions-was actually being turned over to industry as payments on contracts for experimental or service-test sirplanes, 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.

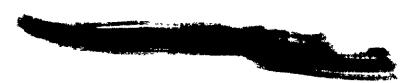
policy of the Air Service to regard experimental contracts as a means of giving support—financial and otherwise—to the aeronautical industries. For example, in 1919 the industry was in danger of being "snuffed out" by cancellations of war contracts and the return to a peacetime sconomy, during the "infancy" 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 Mavy Pursau of Aeronautics, and their representatives on the KACA 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 MACA had spoken warmly in behalf of government support in 1919, 10 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, he shrunken rapidly and is now facing extinction. Until commercial serial transportation becomes a fact, the only demand for such equipment originates with the military branches of the Government. 19

^{18.} Rack, Annual Report, 1919, p. 40.

^{19.} Hemorandum for Maj. Pettis, OAS/W, by C/Air Service, 28 Feb. 1923, in AAF 475.73 Aeronautical Equipment (U).

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Even after the subsequent growth of commercial transport aviation, the Air Corps refused to accept air commerce as enough insurance for an aeromatical 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 sarly 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 sirplanes 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 mircraft, engine, and other aeromautical manufacturers in 1939, the following 34 had substantial experimental design departments and laboratories:

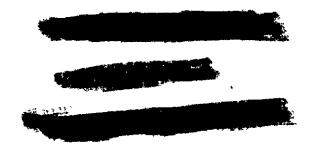
Airplenes

Curtiss-Wright, Buffalo, W. V. (Staff of 5)
North American Aviation, Inc., Inglewood, Calif. (6)
Sterman Aircraft Co., Vichita, Kansas (3)
United Aircraft Corporation, East Hartford & Bridgeport, Conn. (17)
Vultee Aircraft Division of Aviation Kanufacturing Corp., Downing
Field, Valifornia. (5)

Ingines

Continental Motors Corporation, Detroit, Michigan, (Staff of 15) Lycomine Manufacturing Co., Williamsport, Ps. (6) Fratt & Whitney Co., Hartford, Conn. (8)

^{21.} Date in Aircraft Year Look, 1939, pp. 282-463, compared with Industrial Research Laboratories of the United States, 1938.



^{20. &}quot;Distribution of AAF Material to the Allies, 1939-1944: Controls, Policies, and Procedures" (AAF Historical Studies No. 11), Chapter 1.

Accessorism

Aircraft Radio Corp., Boonton, M. J. (Staff of 12) Aluminum Co. of America, Pittsburgh, Ps. (202) American Telephone & Telegraph Co., Inc., M. Y. (Staff?) Bendix Products Division of Bendix Aviation Corp., (Staff ?), South Bend, Ind. (177) Berry Brothers, Ir c., Detroit, Mich. (16) Champion Spark Plug Co., Toledo, Chio, Dow Chemical Co., Midland, Mich. (13) Mclipse Aviation Corp., Bendix, N. J. (18) Fainir Bearing Co., New Britain, Conn. (15) Fairchild Asrial Camera Corp., Jamaica, M. Y. Firestone Tire & Rabber Co., Akron, Ohio. (Staff ?) General Electric Co., Schenectady, M. T. (306) Goodrich Co., B. F., Akron, Ohio. (Staff 1) Leace Neville Co., Claveland, Ohio. (12) Morne-Hoffman Bearings Corp., Stanford, Conn. R.C.A. Manufacturing Co., Inc., Camden, N. J. Shall Petroleum Corp., St. Louis, No. (781) Sinclair Refining Co., E. Y. (125) SEF Industries Inc., Philadelphia, Pa., (11) Socomy-Vacuum Oil Co., Inc., N. T. (Staff ?) Sperry Cyroscope Co., Inc., Brooklyn, F. Y. (25) Standard Oil Companies of New Jersey, (10), Pennsylvania (staff ?), & Louisiana, (53) Thompson Products Inc., Cleveland, Obio. (14) Walter Kidde & Co., N. Y. (5 or more) Western Electric Co., N. Y. (Staff ?) Wilcox-Rich Division of Saton Manufacturing Co., Detroit, Mich.

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; Kallsman 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, 22

^{22.} Research Inboratories in Industrial Establishments of the United States... (Mational Research Council, Bulletin No. 2, March 1920, 130 pp.); and Aircraft Year Rook, 1920.

In addition to direct applied research on simplenes and meromentical equipment, the Air Corps also had an appreciation of industry's resources for "basic research." Aside from the field of aeroneutics, 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 Alcon, General Electric, and Enstman was best known and approminted. Their research findings, the Air Corps stated in 1940, Aquite often compare favorably with those obtained by the Governmental agencies working on ours researchs; 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. 25

Air Corps contracts had been the method for stimulating aeromautical experimentation by industry and for keeping industry in condition for a national emergency. Contracts for military planes rather than subsidies to commercial sir 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 personially 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 quantityproduction orders. Both perties 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 purchese 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 Nevy, or the export market. 24 Industry and Air

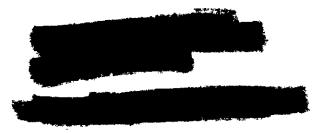
Remorandum for Inspector General by C/AC (written by Maj. E. M. Powers), 18 April 1940, "Aeronautical Research and Development by Commercial Companies, * in AAF 400,112 Test, Development Work,

^{24.} Examples of competition failures and underestimates suffered by the contractors (Martin and Seversky), and of overestimates suffered by the Air Corps (Curtiss P-6 and A-12, Martin B-10) are described in memorandum for C/AC by Chief, MD (written by Maj. B. E. Neyers). 21 March 1939, in AAF 334.8 ACTC ______Bulk* files.



Corps objections were echoed by both the Baker Board in 1933 and the Mowell Commission in 1935, both of whom favored flexible contract procedures, purchase by negotiation, and a system of fixed prices, bonuses, and penalties. In Movember 1938 the Air Corps asked Congress for authority to negotiate experimental contracts as an alternative to competitive bidding, 25 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. s., 10 millions], were pressing Arnold to carry out a more flexible policy. 20 Maj. B. M. Meyers, Budget Officer at Wright Field, surveying the situation historically, recommended a more forthright financial policy in order to mobilise 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. "27 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 angines; and 24.21% on other air equipment, 28 but Wright Field was concerned that unpredictable and excessive development costs might weaken some elements of the industry, including at least two of the sirplane firms, some of the engine firms (both small and large), 29 and the propeller commanies. 30 The remedy lay in megotiated contracts and orderly budget

^{30.} Hilitary-finenced 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." Newsrandum, 10 May 1939, p. 11, in MAS file on "RAD Program, FY 1941."



^{25.} Memorandum for AS/W by C/AC, 8 Nov. 1938, in A. J. Lyon Project Record Book No. 1, quoted in "Legislation Relating to the AAF Hateriel Program, 1939-1944" (AAF Historical Studies No. 22), p. 82.

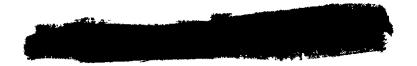
^{26.} Memorandum for Chief, MD, by U/AC, 1 March 1939, in AAF 400.112
Tests and Experiments (U) (filed under 22 March 1939).

^{27.} Hemorandum for G/AC by Chief, ND (written by Neyers), 21 March 1939, in AAF 334.8 ACTC, "Bulk" files.

^{26. &}quot;Legislation Relating to the AAF Materiel Program, 1939-1944" (AAF Historical Studies No. 22), p. 85.

^{29.} Nemorandum for C/AC by Chief, ND (by Maj. B. M. Meyers), 21 March 1939, in AAF 334.8 ACTC, "Bulk" files.

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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 none 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 effecting 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 sconomy, in which research was an important tool of industry for the development of commodities for sale in the competitive market. Nost 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 1936 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 20% of a university's total income: and that America's university achievements in ours science had not been as "remarkable" as Europe's. The survey was not detailed. however. Only 60 of 200 imstitutions 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-as to facilities, subjects of research, or manpower -- for administrative use in the planning of a military research program,

^{31. 53} Stat. 560, 1000.

^{32.} For the legislative history of Air Corps negotiated contracts procedures in 1939-1-40, see "Legislation Relating to the AAF Material Program, 1939-1944" (AAF Historical Studies To. 22), especially pp. 82-98, 101, 152.

^{1.} National Bureau of Standards, <u>Directory of Commercial Testing and College Research Laboratories in Universities</u> (NBS publication M125, July 1936); C. S. Marsh, ed., <u>American Colleges and Universities</u> (American Council of Education, 1938); and Raymond M. Hughes, "Research in American Universities and Colleges," in National Resources Committee, <u>Relation of the Federal Government to Research</u> (1939), pp. 165-193.



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 NACS 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 MACA and the MAS rather than directly. Neither the Baker Board in 1933 nor the Movel] Commission in 1935 included references to the Air Corns in their recommendations on university research on acronautics, an especially significant onission because a university administrator sat on each of the boards. Similarly, both the Kilner Board and the MACA research subcommittee in 1979 inferred that university research for the Air Coros would be handled indirectly through the HACA. 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.} Tabulation, FY 1940-44 inclusive, in M&S "AAF Research and Development Program," about April 1944, in M&S file 700.430 "...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 [V]).

^{3.} Other MAS "basic research" projects, presumably to be placed with universities, were covered in an AC-MAS contract (W535-acl1707) 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), OCAC to MD, 9 June 1939, in AAF 337 Conferences.

^{4.} MACA, Annual Report. 1939, p. 39. The NACA proposed in 1939 to expend 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 MACA.

The Air Corps student at M. I. T., Capt. Alfred R. Maxwell, who was prominent in bombardment development. Saw in the seronautical 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" seronautical research facilities at M. I. T., whose work "certainly compares favorably with that of the MACA," and warned that while the Air Corps was taking "little advantage" of it, the Mavy, the GAA, the NACA, the Corps of Engineers, and firms like Sperry and General Flectric 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 mothing"; contracts with universities would tend to be more economical than industrial projects because the professors were accustomed to petting "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 B-12 Liberty engines, the SE-5 Tenny" planes, and similar equipment on hand.

5. Capt. Alfred R. Maxwell, MIT, to Gen. G. H. Brett, Chief, MD, 29 Jam. 1940, in AAF 400.112 Tests and Experiments (U).

^{5.} Capt. Maxwell (leter Col. Maxwell, Director of Bombardment, and Chief of OCER Hombardment Branch, 1942-44) was preparing a thesis on a phase of bombardment; determination of criteria for design of high performance automatic controls suitable for use in gyro pilots, bombeights.

* 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 1939, in AAF 210.65 Detail Officers—Civilian Educational Institutions (U); Memo for Commandant, AG Engineering School, by Maxwell, 31 March 1940, in AAF 201—Maxwell, A. E.; and memo for Decorations and Awards Branch by AC/AS, OCER, 9 Sept. 1944, in 1914.).

Marwell's estimate of the university research situation was read by various officers in OCAC Headquarters, and General Arnold ordered it sent to the MACA's new "Goordinator of Research," rather than to Wright Field. Apparently it was discussed in the MACA meeting two days later, when the MACA was directed by its Executive Committee to make a Mation-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 Maval aircraft factory as well) that might be suitable for allocation to universities.

This inventory in February 1940 was apparently the first weekle 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 Gorps 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 MAGA efficials. In subsequent months, 30 research projects were to be initiated by the MAGA with some of them, in the field of merodynamics (6), etructures (10), materials (5), 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 Mation-wide mobilization of scientists and laboratories for national defense. This was not to come until 1940. There was nothing in the United States comparable to the German or Italian dictatorship ever industry and education, mor 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 1935. 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 spokemen for

^{7.} Maj. A. J. Lyon, Exec., MD, to Capt. Alfred R. Maxwell, 5 Feb. 1940, in ibid.

^{8.} TI-119 (prepared by Capt. B. W. Chidlaw, ND), 23 Feb. 1940, in <u>1bid.</u>
9. The <u>Directory</u> published in 1936 by the Mational Bureau of Standards (previously cited) included "college research laboratories" but smitted such well-known facilities as C. I. T. and M. I. T.; and its format, arrangement, and odds names made it difficult to use.
10. Telephone conversation with T. L. Smull, MACL, 2 March 1945.

industry and science. The nature and extent of Government control and coordination of industrial, university, and overment laboratories had been conveniently examined by the National lesources Committee in 1938, showing a rich and varied tradition of government coordination of research going seek at least as for as the potent system established by the Constitution, or the agricultural experiment stations begun in 1862. It is a totally innecent to legend that scientists in universities and industry one working "freely," uninfluence" by government guidance and implies a whether for humanitarian, national-preparedness, or other social our case.

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 relection of this or that private organization for the execution of a research project, especially there consistive conditions did not exist; control over the allocation and expenditure of funds; engineering and testing of execution and expenditure of funds; engineering and testing of execution execution and expenditure of funds; engineering and testing of execution and expenditure of funds; engineering and testing of enecific execution and expenditure of 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 econogy, that it wasn't even consciously an issue in 1939.

Nor was this military-rivilian, governmental-private relationship necessarily fatifling on the development of new simplenes or other equipment. The hackneyed historical legend, that new memous have usually been developed in spite of the "traditional atmidity and comservation of military mutherities," if it is correct at all, was hardly correct for Army existion between world for I and world for II, when military requirements had normally been somewhat whead of the state of the art and when the Air Corns research budget had subsidized most of America's advanced peronautical developments. Conservation here and there did exist, merhans, but for from being peculiar to the military, it was likely to be equally characteristic of an engine firm.

^{1.} See its mblication, <u>lelation of the Sederal Government to Research</u> (schington, 1939; 255 pp.)

^{2.} J. C. Fernal, The Social Function of Science (London, 1939), to, 182, nernal indirectly controlleds this statement, however, with smedific exam les dited elsewhere, where he "benome" the efficient but "prostituted" use of science by the military. Other crities have uttered the same observations as to military conservation to eard new vessons, including George W. Grey and heldener Exemptions.

S. The reparent 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 S. C. Gilfillan, "Franciction of inventions," in M tional resources Committee, Technological Trends and Mational Policy. (R. Dec. No. 360, 75 Cong., I wasa., June 1937), part 2, ro. 15-25.

a university engineering department, a government laboratory, or at least portions of each. In whatever type of institution, both each servative 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 naterial 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 organisations, 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.

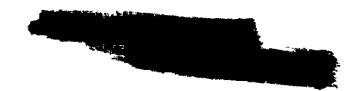
Among the other government agencies that were in any comparable position to exercise control over aeronautical research and development, the NACA was the most plausible and historically in the best position. In 1939 the NACA was not only an active participant in research, as described elsewhere, but 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.

Furthermore, the MACA since 1918 had been collecting information and data on the progress of foreign aeronautical developments, through its "scientific attaches in Paris as well as by other means. Hone of these

^{4.} The British physicist and critic of research administration, J. D.
Bernal, 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, 1939), pp. 77-78.

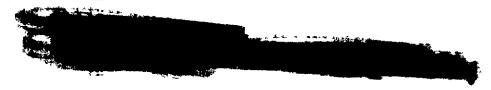
^{5.} J. C. Hunsaker, "Research in Aeronautics," in National Resources
Planning Board,Industrial Research, p. 136. Professor Hunsaker,
at that time (1940) was in charge of the Department of Aeronautical
Engineering at M. I. T., as well as a member of NAGA, Later he
became chairman of the NAGA,



coordinating activities were new in the HAGA except for the sponsorship of university research, which had not been undertaken until after 1935. 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 Unvernment subsidies were defended as an "effective," "economical," and "democratic" procedure for furthering "what has become an international competitions in national preparedness.

The Air Corps in 1939 was inclined to defer to the MACA for the scordination of the fundamental phases of aeronautical science, since the Air Corps (together with the Mavy 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-Mavy isronautical Board, which was given emergency jurisdiction over the MACA 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 MACA should become the coordinator of fundamental research, it needed "new blood and [should be sexpanded sufficiently to assume this function. " Subsequently a Director of Coordination had been established in the MACA, in June 1939, with the blassing 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 MACA assured, in general preferred direct collaboration with contractors working on its projects, unless the research project clearly had broad Army-Mavy-commercial aspects. A further reason for direct lisison, suggested by Cantain Marwell at M. I. T. and probably widely accepted in the Air Corps, was that the engineering students and faculties tended to regard the MACA ms "rather impersonal and overcritical." and "only a source of technical literature," while the Air Corps was

KACA Executive Committee, minutes, 23 June 1939, and preliminary report of Lindbergh subcommittee, no date, about 24 Aug. 1939, both in AAP 400,112 HACA; and NACA, Annual Report, 1940, pp. 21-22.



^{6,} MACA, Annual Report, 1939, p. 3.

^{7.} The Thite House on 29 June 1939 approved a proposal made in Aug. 1938 by the HAGA Special Committee on Relationship of (NACA and) Mational Defense in Time of War, of which General Oscar Westover, then Chief of the Air Corps, was chairman. See MACA Executive Committee, minutes, 15 Sept. 1939, pp. 9-10. in AAF 400.112 MAGA.

8. Memorandum for AS/W by C/AC, 29 Jan. 1939, "Aeronautical Research."

in AAF 400,112 Tests and Experiments (U).

"living and glamorous to most, and a goal of quite a few. "10

Any coordination by the NACA, furthermore, was concerned only with fundamental research, and only in the fields of merodynamics, etructures, power plants, fuel, and some of the aircraft materials. Important as they were, they excluded such equally basic material as air ordnence, electronic sids, optical sids, alloys, and numerous other types and phases of air material, 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 Ordnence 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-Nevy 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 top agency 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 sbout 720, was rather broad, representing, as it did, about 85 national scientific and technical societies, as well as the various Federal scientific bureaus and agencies, and a limited number of members chosen at lerge; and its various divisions and subcommitizes totalled about 1,150 additional scientists and professional men, I. In addition to its supervision of a limited number of technical projects for various agencies, it also disseminated useful information wital to the more effective administration of research, notably its periodical census of Industrial Research Laboratories in the United States, the latest of which had been published in 1938. In 1939, the NEC, at the request of

^{11.} Albert L. Barrows (Executive Secretary, NRC), "The Relationship of the National Research Council to Industrial Research," in National Resources Planning Board, ...Industrial Research (1941), p. 365. See also historical statements on "National Research Council," in Journal of Applied Physics. Aug. 1943, pp. 378-379; and The Government's Nartime Research and Development, 1940-44 (Senate Subcommittee Report No. 5, 79 Cong., 1 sess., 1945), pp. 234-242, 325-326.



^{10.} Capt. Alfred R. Max ell to Maj. A. J. Lyon, 19 Feb. 1940, supplementary to his earlier letter of 29 Jan. to Gen. Brett, previously cited; both in AAF 400.112 Tests and Experiments (U).

the Mational 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 Mational 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 "mot" to volunteer and 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 unvilling " to go. Thus, the Air Corps, when asked early in 1940 whether its limison with the HBC 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-evercest (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 summarise 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 sepen round-table discussions between the scientist and the practical engineer,"

^{12.} The end product of this survey was the 370-page report of the RRG to the MRPB, Dec. 1940, entitled Research—A Mational 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 MAS and the MRC are given in <u>Massings...S. 2721</u> 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 MAS as conservative and "self-perpetuating," am "august body...of mature years..., crystallized in their ideas and their viewpoint...conservative...."



and "direct collaboration" with outstanding authorities in physics, aerodynamics, optics, and metallurgy. 14 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. #15 The bill was never passed. A 1 ter Congressional proposal, early in 1939, for a more limited body, one primarily for "military sircraft engineering" but covering both the Army and the Mavy, 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 sollaboration 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 Yederal-wide Mational Defense Research Committee,

^{16. *}Legislation Relating to the AAF Materiel Program, 1939-1944* (AAF Historical Studies No. 22, Nov. 1944), pp. 104-105; and MACA Executive Committee, minutes, 23 June 1939, p. 4, in AAF 400.112 MACA.



^{14. 1}st Ind., (AG letter 381 National Defense [3-11-40], 14 March 1940), C/AC to AG, 11 April 1940, in AAF 400,112 Test, Development Work.

^{15.} Hemorandum for AS/W by C/S (Gen. Halin Craig), 3 Sept. 1938, in AAF 400,112 Tests and Experiments (U),

IV. VARIOUS RESPARCE AND DEVELOPMENT POLICIES. 1939-1944

Changing Military Requirements, 1939-1944

The Kilner Board's 5-year program of June 1939, and its comservative modification by the Air Board in Sentember 1939, continued into 1940 as Wright Field's immediate and long-term goals. A few additions to the progrem 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. Briti-h and German operations since September 1939 were showing the need for such aids as amor protection, leakproof tanks, turrets, 'e-icing equipment, and (for pursuits) droppable fuel tanks and auxiliary bowd racks. These needs, reported by military attaches, were understored 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 Serreny today not one of them would return. "2 General Arnold. impressed by these observations, ordered re-evaluation of the entire research program by a special board headed by Maj. Cen. Delos C. Emmons (companding general of the GEO 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, added virtually nothing new to the sirplane 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 kay 1940, when the Germans were already

ACTC minutes, 7 Dec. 1939, in A. J. Lyon project record book No. 15.
 Other problems were: assisted take-off and landing devices, armor and bullet-proofing, and greater bomb capacity for pursuits.

^{2.} Memorandum for Maj. Sem. Delos C. Emmons, SG, SHQ AF, 23 Apr. 1940, appointing Samons president of the Board to re-examine the Research and Development Program; copy in AFIRI.

^{3. *}Report of Board of Officers [Ammons Board]...Personnel Order No. 104... May 2. 1940. * (2.38 pp., and tabs); copy in AFIHI.

In Morway but not yet in the Loviands, General Arnold could still cable from Panama (where he was on a temporary mission) to mrge that wortine research and development be vigorenely pushed in the for theoming defense of the budget estimates. Tive weeks later, however, with British troops avacuated from Dunkirk and with France virtually conquered, the strategic situation had become so had that Armeld 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 sirplanes for the Army," while research and development must be given "the lower priority ... consistent with the [above/ primary mission. "D Higher suthority, 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 Mational Defense Research Committee. B-Day had been set at 1 October 1941 by the Chief of Staff, and the airplanes needed. Armold stated, were "not these which will be produced four years from now, but these to be delivered within the next six months or a year, certainly not more than two years hence."

The research program was not acrapped, 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 impertant airplane projects were selected by the Emmons 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' expecities for experimental work;

^{4.} Maj. Gen. H. H. Arneld, C/AC, to Maj. Gen. B. K. Yount, acting C/AC, teletype, 8 May 1940, in AAF 581.4 War Plans, Mational Defense (U).

S. Memorandum for Chief, MD, by C/AC, 6 June 1940, in AAF 462.1-17 Airoraft--Manufacture of (U). Arnold had also verbally directed the
Emmons 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, 1July 1940, in MAS file on "RAD Program, FY 1941."

^{6.} Memorandum for Exec., OCAC, by C/AC, 14 June 1940, in AAF 400.112 Tests and Experiments (U).

^{7.} Memorandum for Maj. Gen. H. H. Arnold, C/AC, by Brig. Gen. B. I. Yount, Asst. C/AC, 7 Oct. 1940, attached sets of priority schedules, and comments by Maj. B. W. Chidlaw, MD, 20 Sept. 1940, all in AAF 452.1 Air-planes, General.

1. 5,335-mile very heavy bember (B-29, 30, 32)

2. 2-engine interceptor (Leakheed XP-49, Grunnan XP-50)

3. 2,667 mile medium bomber (North American XB-28, 28A)

4. Recort fighter (Lockheed IP-58)

5. 1-engine interceptor (Valtee XP-54; Carties XP-55, Northrep XP-56)

6. Eavy dive bomber

7. Light bomber (Murtin MA-23)

8. Long-range bomber (8,000-mile range)

9. Observation sirplane

10. 2-engine trainer (Beech AT-7A)

These priorities were not to be rigid, because of "the constantly changing military situation abread." the capacity of the industry "to absorb...experimental development without interference with the approved procurement program," and the extent to whigh 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 preduction 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 deferment of such projects (where production delays could be demonstrated) "until such time as airplane deliveries are up to schedule." At the same time the MAGA laboratories were also affected: wind tunnels and other facilities were diverted from "basic research" in order to concentrate on impraving 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.

^{6.} Hemorendum for AG by Brig. Gen. B. K. Yount, acting C/AS, 17 Aug. 1940. in MAS file. "FY 1942 RAB Program": based on memorandum for U/AC by Chief, NB, 17 Aug. 1940, copy in AFIRI and in AAF 400.113 Research and Development Programs.

^{9.} Memorandum for Chief, ND, by C/AC, 12 Sept. 1940; referred to Wright Field as TI-342, 16 Sept. 1940; both in AAF 452.1-17 Airplenes, Hammfacture of (U).

^{10.} MD letter to all contractors, 8 May 1941, in AAF 400.112 Test, Dovelopment 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 Angle-German air war. In 1940, the turret and armament mission by Lt. Col. Grandison Gardner and Maj. F. O. Carroll, 2 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 portain phases of material over others, and contributed suggestions as to more fruitful avenues of research. Cortainly the work on turrets and radar detection and ranging were all presecuted with greater vigor directly as a result of these Air Corps missions abroad. In the next year, the mission of General Arnold to Lendon (in April-May 1941) likewise raised the priorities for high-altitude pressurising, jet propulsion, controllable bombs, gliders, photography, and external fuel tenks for range extension, at the same time confirming Air Corps superiority of turbe-superchargers, campon installations, .80 caliber guns, bombsights, and mir-sooled engines. 18 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. Eaker'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 tectical and experimental experience on Air Corps majorial 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

12. Report by Gardner and Carroll, 1 July 1940, quoted in ATSC historical study, "Power Turrets" (draft), Chap. V, note 24.

15. Col. Ira. C. Eaker, "Report on Trip to England," 50 Aug.-1 Oct. 1941, Z vols., in AFIHI, "Col. Moore's files."

^{18.} Many but not all of General Arnold's conversation and deliberations are described in his cablegrams from London to Washington, in AAP 311.22 Cablegrams (filed under 5 May 1941). See also Edward Warner to T. P. Wright, writing from London, 22 April 1941, in AAF 381.3 Lend-Lease Aid (filed under 12 June 1941); and WF to Chief, MD, teletype, 13 June 1941 (copy), in MAS file on MFY 1942 EAD Program."

^{14.} Interview with a former member of SPOBS, Brig. Gen. N. H. HgClelland, ACO, about 9 Jan. 1945. The Air Technical Section of SPOBS, headed by Cel. (later Brig. Gen.) A. J. Lyon, later was placed under ETOUSA, and after about Oct. 1942, was headed by Cel. Howard, G. 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 expended. 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-Newy-Britishmircraft 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 1041, passed the following March: 16 and the various war plane in preparation in 1941 for joint participation of American air forces with the British, 17

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 50 additional developmental projects for General Armold'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. Similarly, one of the special observers in England early in 1941 (Maj. John G. Noore) was told by the British Himistry of Aircraft Production (Sir Henry Tisard, Except 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."

^{19.} Final report to G-2 by Maj. John G. Koore on his visit to Great Britain, 11 April 1941, in Air Intelligence Library, MG. S.-9545.



^{16.} For all these steps in 1940 and 1941, see "Distribution of Air Materiel to the Allies, 1939-1944..." (AAF Historical Studies No. 11. July 1944).

^{17.} ABG-1 plan, 27 March 1941; Atlantic Conference, 11-14 Aug. 1941; AWFD/1, 12 Aug. 1941; and Arcadia Conference, 23 Dec. 1941, AFIHI study, "Review of Aerial Variare for the Scientific Advisory Board [Group]," Jan. 1945, pp. 15, 16, 18.

^{18.} Nemorandum for Armold by Maj. Gen. George H. Brett, "The Assistant," 27 Feb. 1941, im AAF 400.112 Research and Development Programs.



The Air Corps accepted the pressure of war im 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 sollaboration (discussed later) that was to vex all parties during the rest of the war long after the enemy occupation of England coased to be an immediate threat.

After America officially entered the war in Becember 1941 the military requirements for new material continued to shift, properly, with changes in strategic and tactics) plans, including greater emphasis on future needs in the Japanese theatres of war. The whole develormental program at Wright Field had grown to about 2,000 different projects by December 1941, Franging in score from a complete airplane down to an improved type of cowling. The special Kenney Board was maked in January 1042 to review the sirplane development program and to recommend military characteristics for various types, including a 10,000 mile bomber and an "interin" long-range bomber with a range somewhere between the B-29 and the 10,000 mile bomber, 21 showing the increasing preoccupation with the Japanese theaters of operations. The next menth 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" angines, ergines in the 4,000-5,500 horsenower class for use in the very lone range bombers, and controllable bombs and glide tormedoes. The whole story of changing military requirements cannot be treated in detail here, 22 except to note that

is planned. See also daily disries of Director of Military Requirements, Narch 1942 - March 1943, and of AC/AS, Operations, Commitments, and Requirements, April 1943-date, both filed in AFIHI. 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, Bopbing Equipment, Reconnaissance Airplanes and Photographic Equipment, and Power Plants, to mention only those in active preparation (as of March 1945). See also ATSC Mistorical Office "case historical" 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 AFIHI.



^{20.} Memorandum for M. M. Bundy, OS/W, by Brig. Gen. M. S. Fairchild, Asst. C/AC, 25 Nov. 1941, in AAF 400.112 Research and Development Programs.

^{21.} Hemorendum for Brig. Gen. George C. Kenney, no date, unsigned, in AAF 360.01 Programs (filed under Jan. 1942.)



after December 1941 by for the greater implies came from America's own combat hir forces than from the British, and that "thecter requirements" dame from both the "process and Pecific areas, not each office leaver but import at thecters and, he the outimandmarine some in the North and South Ablantic. By carly 1944, of the tatul reported and development program of some 1,000 items, the fallowing of a managed of Barner are jected by constant and his is ediate him of after.

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XJ=817 and C, Y =50, XZ=70, XZ=70, XZ=70, YZ=80 fighters
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^{2°.} Lemon ndum for Brie. Cen. 3. 1. Chidles by Col. R. C. Milson, both in a 20, 7 Jun. 1944, Pieting Manner projects writed by CC/AS, in 1 Time #18.100 hier.—len. 4 The total firme of 1,000 nmje to in only a provincte: in oc. 1001 it are 1,000; in July 1944, 1,390; the appearance of Commands speciment of the content of Commands speciment of Jan. 1944), while not constate, listed only about 200.





Inels.

Grades 94/114 and 110/150 *super* fuel

Committies Gum Sights

K-14 (British Mark II C), for fighters K-8 (Fairchild) and K-9, 10, and 11 (Sperry), for bomber turrets

B-29 fire control

General Blestric, Sperry "local", and GE 4-gun umper forward turret

B-32 fire control

Sperry A-17 (note and tail), Martin A-3D (moper), and Sperry A-13 (ball)

20 m turrate

General Electric upper and lewer remote, and remote tail Martin and Emerson upper cylindrical types Sperry ball (2 models, one 44 %) Sperry nose and tail

Others

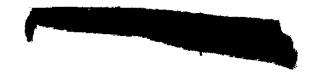
British flame thrower, airborns Havy racket, type 3.25

Still other especially urgent projects were added during 1944, notably additional guided missile projects, inspired by the intensive use of robot bonbs by the Germans after the Mormandy 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 1939-19:1, before American entry into the war, this system was centralized in the Plans Section in the immediate effice 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 AC/AS Plans (April 1943—to date). The latter offices normally did not formulate either quantity or quality requirements. Occasionally their disries revealed that they commented on staff studies and Rik's from Requirements or Materiel, and now and then prodded them in behalf of perticular projects, such as glide bombs (1942) and rescue equipment (1943).

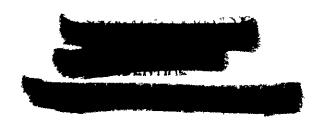




Chief of the Air Corps, supplemented by a committee usually representing OGAC headquarters, the tactical arm (the GHQ Air Force, established in 1935), the General Staff, and the Materiel Division. This committee, which was known as the Air Corps Technical Committee between 1936 and 1939, was apparently abandoned after its last meeting in December 1939, being meanwhile superseded in part by such ad hor agencies as the Kilmer Board in March 1939 and, later, the Mamons 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 directives. 26

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 Auril 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 Material Division in RMAD "supervises the development, procurement, and production of aircraft, equipment, and supplies...[by] the Materiel Command. "25 CCAR officers occasionally went beyond prescribing "what is wanted" to direct "how" the directive was to be carried out by Material. Their frequent contacts with project officers at Wright Field, although "informal," accasionally 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

^{26.} OCAR O. H. No. 9, 23 April 1943, in MAS file "18,100 Misq. Gem.".
This directive is similar to the one issued a year earlier, shortly after the Directorate of Military Requirements was established in March 1942. See IMR O. M. No. 9, 17 March 1942, in AAF 300.6 OCAC [sie] Memos, Numbered (U). See also DMR O. M. No. 12, 25 March 1942, and No. 13, 25 March 1942, both in ibid.



^{25.} Kemorandum for Chief, MD, by Maj. N. E. Gross, 27 June 1940, reporting informal conference including Gen. Arnold, Gen. Brett, Col. Mchols, and others on 15 June: in MAS file on "FT 1941 MAD Program."

preservined proceed to were not infrequent. I am apprently were remedicd therever the striff officers concerned were made aware of then, 'aj, Jen, H. A. Crig. 10/13 Coak, and Brig. Cen. H. E. Gross, his whise of emirenests, ettempted to reconcile informal directness and formal channels by means of an office order in April 1944 on the subject of industrial linison, that "Co project officers "will m ke no commitments. Tive no instructions, and make no statements to manuficturers which, in any way, night be construed as as approved by this headour rights of saything being done by the manufacturers or contemplated by them. "In October 1964, when when when stars for the reorganization of the entire CAF Handquarters were again under way, the problem of dateriel vs. Tequirements was again aired, but neither whiff office mently submitted a drastic recommention, and the olan child for no reorganization of development and requirements functions. 39 Requirements marely observed that features care is now being exercised to insure that in the but we this finterference of endrements with hiternel's supervision of the development program. will not impend; and recommended that in the cross M&S and ATDO be given more experienced personnels to make unnecessary the occasional deni tions from normal chunnels by hequirementa officers who were more intimately femiliar dith a given project.

Sup Jeconting the requirements system but indirectly (through the AAF Board) reminder moder TCAR was the work of the AAF Equipment Board at Calanto, "la, established about January 1945 in order (among other things) to handle "the problem of linison with the various theaters, study of different conditions, and the establishing of military charactersistics for wisce language light, equipment, "Il

^{27.} For samples of complaints, see memorandum from Wright Jield (Lt. Col. C. V. Tims), 16 March 1942, in ANF 381 Mar Trojects; minutes of medial Tirectors Conferences, 19 June, 27 Aug. 1942, in ANF 337 Lecial Directors Conferences; 1952 Interial Division, diarr, 27 June, 1943, and 30 Tarch, 26 Sept. 1944; and memorandum for Col. J. Z. hilli s av d. R. Gratchen, both in M&S. II aug. 1944, in M&S file Tip. 100 Histor.—Com. N

^{26,} moted in inutes of "All staff meeting, I April 1944, in MaD retariel ivision file of staff-meeting minutes.

^{29.} Tenerandum for C/AS by Gen. Arnold, 30 Oct. 1944, in AN 316.1 office a ministration... (filed under 3 Nov. 1944).

^{30.} Let, 1822 Requirements Pivision to 10/49 SC&R, 17 Hov. 1944, in ibid.
31. Association for Pirector of Rase Services (Col. L. . hitten) by
Siler of Staff (Col. 3. K. Chidlaw), Lateriel Sommand has, 22 Jan.
1943, in MAS file 418,100 Miss.—Gen. Widthword Fright Field
officers had discussed the work of the new Soard with Gol. McGregor,
magnetic head of the Pored.



Presumably items developed and procured by non-AAF supply services of the Army were to be more closely followed, although its testing activities covered items developed by Wright Field's Equipment Laboratory on well.

Ultimately there perhaps was no workable alternative for close collaboration between the planners of research (Requirements) and the supervisors and monitors of research (Materiel), whether the collaboration was to take place in formal committees or in informal dayto-day contact. The committee system, presumably abandoned in 1940, was actually revived from time to time under assumed names. The AAF Material Flamming Council, set up in July 1942 with members from the Directorates and from Materiel Command headquarters, while it was preoccuried with the fuller futilization 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 atrophied 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 prejects jointly by MAD and OCAR, 33 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 schelons 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 AAP Materiel Demobilization Plan of 23 September 1944 and "Project B-7" 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 Gernany'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, \$34

^{32.} Minutes of Special Directors Conferences, 7 July 1947, in AAF 337 Special Directors Conferences. Col. Edmund C. Languese represented Material Command Hqs.

^{33,} Other staff offices also were represented, including the 26/A5's and Training. MASS Materiel Division, diary, 21 March, 5, 7, 21 April 1944; and correspondence in AAF 380 Programs and Projects (April-May, and Oct. 1944.)

^{54.} AC/AS MAS daily activity report, 4 Oct. 1944. The *B-7* postuar 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 serial weapons could not always be rigidly channelized, 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; 35 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 Armold). 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 "everall strategic planning in its early stages", instead of leaving the radar scientists and officers "engrossed in the physical devices themselves, on the one hand, and the strategists concerned with their specialities, 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 OGAR, and was intended to represent not only OGAR and MMAD but also other Air Staff offices, including the Air Communications Officer, the AC/AS for Intelligence, as well as officials technically outside the Air Staff, such as Dr. Powles and the President of the AAF Board at Orlands, Flm. 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. 38 Its discussions

^{38.} Memorandum for committee members by AC/AS OCAE, 6 July 1944, in NAS file #30.105 New Developments Division. ** Sumerous suggestions for discussion by the Committee, assembled from the various project officers in MAS by Col. R. C. Wilson, July - Aug. 1944 (filed in MAS file #30.109 Committee on AAF Development*), pertain to engines, fuel systems, propellers, symment, guided missiles, photography, and navigation sides.



^{35.} See drafts of Historical Division studies on "Radar and Radio Equipment" and "Communications Techniques" for discussions on the relation—ship of ACO to material requirements.

^{36.} For a history by Dr. Bowles of his group's activity, see his memorandum for S/V, 23 Aug. 1943, "Resume of Consultant Activity," in AAF 334.7 "Bulk" files.

^{37.} See inter-office correspondence on this committee, 23-27 June 1944, in AAF 334 Boards...Nisc.



were a prently phondamed by September 1974. Toward the close of the year untiler counittee was established, this time a group of civili a correlative known as the Picientific Advisory Group, headed by ir. Theodore was Frame, and attached to the immediate office of the Chief of the bir Staff. Among its duties this Group was directed.

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One of the station, in March 1945, concerned languarance, an recomic, rocket-crossited suited missiles of the V-S type, both chared and characters. AG

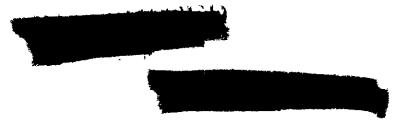
In idea and aromon's from all these and other sources were in lin with Ceneral Armold's demand, voiced in his staff talks on the new landment I dir Force, that the its Staff and AAT Headquarters must continue to look forward, that staff officers must be alert to new ideas, even to the extent of questioning specific aspects of current meteric development, current tactics, and querent strategic plans. Idea of four and environment, when, and have there early to be encouraged. Thether, then, and have the error to be translited into the agent in military require ents as the in the Preserval and development programs remained, however, as for loar of the staff officer concerned lirectly with those classes.

Amendon of MCA Laboratories, 1389-1944

The extension of the serodynamic and entire research facilities of the Man was basic to the prosecution of the Air Cor a development page of and after 1939 there was little resistance by Congress or the orear to the financial of MAC, activities.

churacteristics on that 185 records a staff study on a change in the shinistritive remonsibility for movellent records, presumbly only from the from the from the following forms.

Dea Morreintion Relating to the NAM rateriel Program, 1939-1944*
 Pistorical Studies No. 27, Nov. 1944), np. 192-121.



^{39.} Thated in Minutes of staff meeting of 700, 10 Teb. 1945, in AZIHI.
40. 2775 CONT. Soily acti ity report, 12 Forch 1945, in CTIHI. CLER recommended that the cientific Advisory Troup present the military communication and that 365 france a staff study on a charge

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

1940	4 ,374,546
1941	11,200,000
1942	19,865,910
1943	25,428,736
1944	38, 392, 215
194B	•

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

^{2.} Senate Committee on Military Affairs, The Government's Wartine Research and Development, 1940-44 (Subcommittee Report No. 5, 79th Cong., 1 sess., 1945), p. 314. Another tabulation, by appropriation act rather than by fiscal year, is given in "Legislation Relating to the AAF Materiel Program, 1939-1944" (AAF Historical Studies No. 22, Nov. 1944), p. 152.

Emenditures by the HAGA, 1939-1944		₩.
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enditures by the NACL 1939-1944	- 1	8
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ares by the NAGA. 1939-1944		27
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	77 1940	1941	1942	1945	7944
Langley Laboratory	\$3,857,215	\$4,507,864	\$ 5,489,93 9	\$ 6,080,398	\$14,574,904
Ames Laberatory	2,705,177	3,506,297	8, 482, 868	4, 737, 315	4,691,673
Cleveland Laboratory		1,165,868	13,950,206	8,343,068	12,705,263
MACA administration and overhead	203,366	354,903	354,506	391,346	427,035
Funds transferred to universities	25,000	111,921	274, 497	344,301	202,455
Funds brausfarred to Mat. Hur. of Standards	70,000	100,000	100,000	142,300	131,634
- Tunds transferred to industry		2,791	22,900	49,001	
Motel expenditures	\$6,860,756	\$8,649,644	\$26,674,608	\$20,087,729	\$32,732,964
3, Summarized from financial tabulation in The Government's Martime Research and Development. 1940-44 published by Semate Committee on Military Affairs as Sub-sommittee Report No. 5, 79th Cong., 1 see	on Military	he Government	t's Martime Res	earch and Deve epart No. 5, 7	Norment. 1940-44
published by remains commissed on military Aliet's se kindrometalism.	om minclude (Amerika mo	destruction	aroanditures.	THE POST OF THE PERSON NAMED IN	CAS: ACRES T BAN

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 Asronautical Laboratory at Moffett Field, Calif., and finally (1942) at the new Engine Research Laboratory at Cleveland. By 1945 the NACA's 170,000,000 plant contained 30 wind tunnels, including the mammoth 80-foot tunnel for full-scale airplanes at Ames, perhaps the largest and most costly piece of scientific apperatus in the world; a 1,200-mph supersonic tunnel; and two special tunnels at Chweland 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 sircraft manufacturers, and 4 sach at the AAF and the Mavy establishments—none of them were as large, versatile, and as highly specialized as the equinment of the MACA. Only the Federal Government could undertake the construction of such equipment and make it available to industry and the military as a "community service."

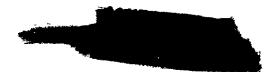
The NACA's personnel strength likewise grew, from 576 in July 1939 to 1,793 in Jenuary 1942 and 6,252 in February 1945. In terms of professional categories, the distribution of employees was as follows (as of 1944): 27%, empineers, pilots, physicists, methematicians, chemists, etc.; 38%, scientific aides, computers, laboratory assistants, draftsmen, mechanics, tool-makers, pattern-makers, etc.; and 35%, clerical and other non-professional workers.

^{4.} The NACA also had an "ice research center" at Minnessolis in 1942. Mentioned in AAF 452.1 Assignment (6 Oct. 1942).

^{5.} Several historical sketches on the expansion of the MACA in World War II have been released to the general public: an address by J. F. Victory, Tecretary of the NACA, 23 March 1945, in Cong. Rec., 79 Cong., 1 sess., A1568-71 (24 March 1945); George V. Gray, "Trial by Vind Tunnel," Harpers, April 1945, pp. 446-455; Senate Committee on Filitary affairs, The Government's Varthme Research and Development, 1940-44 (Subcommittee Report No. 5, 70 Cong., 1 sess., 1945), pp. 180-184, 314; and "Mational Advisory Committee for Aeronautics," in Journal of Applied Physics, Aug., 1943, pp. 399-405.

^{6.} Vigures received by telephone from NACA Personnel Office, 25 March 1945.

^{7.} Senate Committee on Vilitary Affairs. T. a Government's Wartime Research and Development. 1940-44 (Subcommittee Report. No. 5, 79 Cong., 1 sess., 1945), p. 181.



The wartime expansion of the MACA mormally had the approval and support of the AAF. This support usually took the form of defending MAGA budgets before the Budget Bureau and Concress, appealing to the War Production Board for preference ratings for materials and equipment wanted by the MACA, seeking a more liberal draft deferment policy for the younger technical men amployed by the MACL, and supplying the MACA with aviation fuel and lubricents. In some cases, however, the MACA was in competition with the AAF for men and materials, and 1005 support by the AAF was denied. Thus, in July 1944, MAD sriticized MACA for seeking White Mouse support for the very highest WPB priority for jet propulsion test facilities, at the expense of the work of the AAF on fuel injection "and other must projects", although earlier (im May) the AAF had supported the MACA in getting what it regarded as adequate priorities for the construction of a supersonic wind tunnel. Similarly in August 1944, M&S (successor to MMAD) non-concurred in an MACA proposal to seek 1,000 additional civilians through the Civil Service Commission, because the "only source" for such employees would be the AAF -- the Materiel and Air Service Commands.



^{8.} Minutes of MAS staff meeting, 15 July 1944, in HAS Development Engineering Branch file on "staff meetings"; MASD Material Division, diary, 31 May 1944; and joint letter to WPB by Gen. H. H. Armold. Adm. B. J. King, and Gen. G. C. Marshall, 26 May 1944 (copy), in MAS file #700.280 HAGA.*

^{9.} Minutes of MaS staff meeting, 26 Aug. 1944, in MaS Development Ingineering Branch file on "staff meetings".

Expansion of AAF Experimental Facilities, 1939-1944

The transmission of the research budgets for the AAF between 1939 and 1945 is shown in this tabulation, by fiscal years: $^{\perp}$

1939	\$ 3,574,290
1940	10,000,000
1941	102,231,275
1942	98,198,615
1943	113,342,636
1944	121,647,605
1945	

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

^{1.} MAND and Material Command tabulations, covering "projects" 71, 72, and 73, no date, about April 1944, in MAS file 700.430 "... Kilgore Committee"; later published by Kilgore Committee, The Government's Martime Research and Development, 1940-44 (1945), p. 305.

^{2.} Tabulated from let ind. (basic unknown), AAF Hqs. (MMAD) to Director, Budget Division, OC/S, no date, about Oct. 1943, in MAS file "700.430... Kilgore Committee."

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Squiyaent Lab.	25% 400, 31		184,900,63	7.182,889,16	5, 550, 652	4,511,550	
Series and Anna Series Series	25.050, 25.	44, 301, 94	167.013.64	59,093,42	182,862 ces.200	147,150	
Pougr Plant Lab.	1,782,396,59		61,800,00	8, 703, 956, 25	D, 054, 798	0 353 645	
Mechiner & Lab. Stubent		1.033,880,14	1,307,638,55	5,188,553,89	3,078,619	2,000,000 2,001,000	
Buildings & Grounds		655,255,7E	697,027,62	809,634,44	1, 314,015	1,195,800	
	214. 548. CZ	7.8, 501, 913, 89	3,289,017,58	1.052.232.40 64,953,430.50	10 177 CO	2,119,000	
	Cirilian Par	Carillan Parmil for Beagner and Develoument, 1939-64	ch and Develor				
Chiaf & Cecimical Staff	\$ 699,145	See ESE		* \$60 000	CEL STA	340 031. 5	
Asso-Madical Leb.			102,000				
Arrenant Lab.	280 p30	380,000		524,730	787,774	969,075	
Engineering Shops Lab.	306,870	427,930		285°,730	455,000	534,131	
Naulyment Lab.	198,800	354,430		372,890	028,088	843,886	
Photographic Lab.	57,500	152,550		214,730	866,585	306,904	
Power Flont Lab.	347,000	494,230		668,130	995,837	1,174,340	
Frobeller Lab.	95,730	135,250		361,130	306,108	628 563	
Machinery & Leb. Squimment Suildings & Grounds					860 * 988	504.40I	
Flight Section Ceneral Expense					1,088,258	1,091,870	
TWO IS	1,80%,326	2,33,33	102,000	3,330,833	6, 982, 409	8,138,110	
		Werle lett Frencitures 1939-44	enditures 1939				
Chief & Technical Staff	45	\$ 4,703,105.00 \$	4,703,105.00 \$39,830,811.76 \$	3,532,635,60		\$15,831,600	
Afrenat Lab.	23, 330, 91	6,735,431,49		107 545	85,890 854	413,000	
Armement Lab.	34,336,11	177, 125, 10		119,466,96	13, 323	235,000	
Squipasat Lab.	62,648,55	2,203,341,38	2,986,01	57,915,62	540,998	350,000	
Notographic Lab.	2 - 10 - 10 - 10 - 10 - 10 - 10 - 10 - 1	201.514.53		12,500.	and the second	900°09°	
Forest Flant Lab.	40,871,11	96, 883, 38	719,043,66	4,956,956,24	6,837,992		
Control of the second s	04° 11. 4° 50° 0	7,716,00		56,677,24	21.7,008	980°000	
	233, 200, 69	14, 278, 777, 11	43, 555, 441, 42	9.E08.981	0.599.081	19, 998, 000	
	N. C.				4		
		2					
まらい							



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:³

	Civilian	Officers	Rnlisted Men
1 July 1939	1,759	149	76
1 July 1940	2,478	225	104
1 July 1941	4,841	233	83
1 July 1942	10,903	1,220	479
1 July 1943	10,412	1,718	5.146

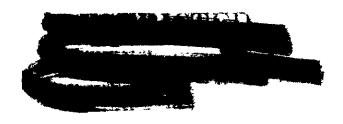
What percentage of this staff was engaged on research and development projects is not known for these years: perhaps at least a third is a conservative estimate. In 1944, more precise figures are available, revealing 5,976 persons engaged in research and development activities, divided as follows:

Civilians Officers Enlisted Man

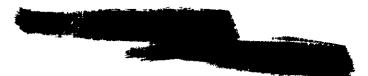
Directors or supervisors	181	268	3
Professional research workers	404	799	56
Laboratory and Vechanical Assistants	1,494		1,975
Legal, c'erical, and others	654	14	128

While only 20 to 25% of them 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 Wasnington offices (AC/AS, MMAD) included 22 officers and 21 civilians "directly engaged in supervisory control of the Research and Development Program."

^{4.} MMAD, "Army Air Forces Research and Development Program," 19 pp., no date, about April 1944, in MAS file "700.430 ... Kilgore...."



^{3.} Material Command Historical Office, "Ristory of the Material Command, 1926-41," p. 6a.

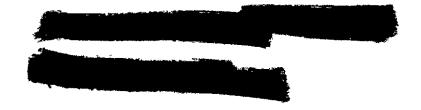


Experimental facilities were likewise expanded, perhops tenfeld between 1939 and 1944. In terms of expital investment, Wright
Field's plant grew from 10 millions in 1939, to 35 millions in
December 1941, to nearly 54 millions in April 1944, financed partly
from the Research and Development budgets (listed 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 diffioult 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 1964).

Capital Yelus of Fright Mield Technical Pacilities, 1944

Laboratory	Laboratory	Technical	Total
The state of the s	Stratures	Instrument	
Aero Kedical	270,00 0	30 0,000	470,000
Aircraft	5,100,000	5,100,000	11,200,000
Alrerait Redio	2,001,000	6,140,000	8,140,000
Armement	1,300,000	500,000	1.800.000
Engineering Shops	2,000,000	1,080,000	3,080,000
Equipment	1,800,000	1.500,000	3,300,000
Flight Section	5,300,000	250,000	5,050,000
Materials	700,000	600,000	1,300,000
Photographic	200,000	600,000	800,000
Pover Plant	6,100,000	7,200,000	13,200,000
Propeller	2,400,000	2,300,000	4,600,000
Technical Data	300,000	400,000	700,000
	28,470,000	25,770,000	53,740,000

^{6.} Ibid.



^{5.} Statement by Brig. Gen. C. P. Mehole, in <u>Flying</u>, Dec. 1941, p. 83; and *AAP RAB Program*, 19 pp., no date, about April 1944, in MS file *700.430 Kilgore...*.

Among the outstanding facilities were the following, spread acress the changing map of Wright Field; Aircraft Laboratory: wind tunnels, both vertical and horizontal, for tests at various simulated altitudes and at supersonic speeds; atructures test equipment; design and mock-up acilities for scale construction; sngineering, vibration, and other equipment to determine suitability of aerodynamic, structural, wibration, and flutter characteristics. Aero-Medical Laberatory: altitude chambers; all-weather room; contribute equipment; animal-research quarters. Armsment Laboratory: armsment firing and calibration rooms; gun ranges; altitude chamber. 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; celd room; X-ray room. Photographic Laboratory: dark rooms; camera workshops; sold rece. Power Plant Laboratory: engine test stands; jet propulsion test stand; dynamometers; fuel test squipment; torque stands; supercharging room; calibration room; altitude equipment; cold and tropical weather reces. Propeller Laboratory: propeller test whirl rigs; torque stands; wibration rooms.

Outside of Wright Field were several additional facilities under the jurisdiction of the same command, including the guided missiles test site at Murec Dry Lake, Calif., established in 1961; the glider test field at Wilmington, Ohio, about 1942; racks for "exposure durability tests" of coatings, plastics, and other materials at the Hemestend (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 sirberne 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 insepsitably associated with radio and radar development", and that the latter must be

^{7.} Ibid. See also "Master Plan" of dright field in M&S/Air Installations Division; and various aerial photographs of Wright Field over the years 1926-45, in Material Command Historical Office. "History of the Material Command, 1926-41", appendix.

^{8.} The long history of Air Corps-Signal Corps relations sennot be recited here. For a brief discussion, see "The Development of Radio and mader Equipment for Air Operations, 1959-1944" (AAF Historical Studies Mg. , draft, Aug. 1944).



treated ... as a part of the main problem of sircraft design and operation rather than as accessories. In this hift the AAF inherited the fignal Corps facilities at Wright Field (chiefly the Aircraft Radio Laboratory, built up ever many years adjacent to the Air Corps laboratories), together with an estimated 195 efficers, 170 emlisted 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 Revelopment budget estimates for radio and radar work were expanded, and additional facilities were foreseen. In this direction Mas 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 torpede," and controlled wing bombs. The Materiel organization, and the AAF as a whele, were precocupied with other more urgent development prejects 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 Mignal Corps, and Materiel officers were sware, like the chief of the Armament Section in Mashington 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. *13



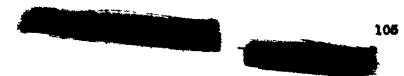
^{9.} Memorandum for Wemerals Arnold (AAF) and Somervell (ASF) by C/S. 26 July 1944 (photostat), in NAS file "30.105 New Davelopments Division."

^{10.} Ib1d.

^{11.} AC/AS, OCAR, daily activity report, 8-9 April 1945.

^{12.} Brig. Gen. C. P. Echols, Chief of the Material Division, had expressed doubt that there would be "enough testing there at Muros te warrant a special detachment." Quoted in transcript of telephone conversation, Brig. Gen. Carl Spants to Brig. Gen. M. S. Fairchild, 4 Nov. 1941, in AAF 311.2 "Telephone Conversations for Gen. Spants" ("Bulk" files).

^{13.} Memorandum for AC/S-E. Nateriel Commend Mag. by Col. V. H. Joiner, 8 March 1945, in AAF 380 Programs and Projects. Joiner urged more collaboration with the Mayal Research Laboratory, the MIRC Radiation Laboratory, and three firms—Fairchild, Douglas, and Interstate.

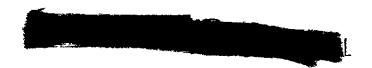


In June 1944 guided missile development was given a new impetus by the spectacular use of robot bombs by the Germans, together with a growing interest in guided missiles on the part of the senior air commanders overseas. The expansion of the Special Venpons Unit at Wright Field was approved by General Arnold on 11 July, salling for about 250 extra personnel and additional construction at Wright Field and at the Muroc Air Base; and in September, Military characteristics for various new missiles were established as the basis for the fature development program. Involved also was the probless of whether the AAF would achieve full jurisdiction over the program, in both its tectical and material phases. The Army Ground Forces, the Army Service Forces, and Orenance all were interested in controlling development of those missiles that were "ground launched"; the AAF was interested not only in "merodynamic" 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 chifted to the ALF 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 seredynamic missiles regardless of how launched; the ASF to develop all ground-launched "momentum" missiles, with military characteristics coordinated by Army Ground Forces; and in either case, "ultimate tactical employment" net 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-rad); but war heads, nonintegral 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 "soupromise" agreement



^{14.} MMAD Materiel Division, disry, 36, 30 June, 10, 12 July 1944; memorandum for U/AS, by MVAD, about 11 July 1944, in AAF 380 Programs and Projects; and memorandum for Ordnance Department by U/AS (written by Col. F. H. Richardson, MAS), 7 Sept. 1944, in AAF 360.2 Development and Research.

^{15.} AC/AS Nas. daily activity report, 14, 19 Sept., 10, 15 Cot., 1944



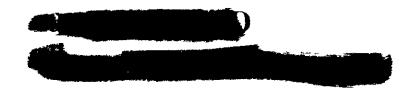
between tactical commands and between procurement services, according to the Chief of the CCAR Requirements Mylgion:

It is probably not the best that could be done, but nevertheless, it is one of which complete agreement was possible at this time. ... Ferhaps 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 shead. 16

Expansion of AAF Service Test Facilities, 1939-1944

Before World War I service and tactical tests of airplanes and equipment were a joint function of the materiel center at Wright Field and of the tactical arm (the GMQ 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. Buring 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. M. W. Schroeder's "testing and proving squadron," about 1918-21. In 1937, after the CEQ Air Force was established (in 1935) as the tactical air arm, the latter supplied a detachment at Patterson Field for service tests, apparently in accordance with a recommendation of the Bryden Board in favor of Patterson Field, to permit the test detachment to take "full advantage of the engineer-ing facilities at /nearby/ Wright Wield and the remain facilities at Patterson Field, and ... permit the engineers at /both/ Fields to be In constant touch with the tests. The testing setivities continued in 1941, under the reorganized Air Force Combat Command, and the test

I. Recommendation of the Bryden Board, 22 July 1936, in AS 400 (4-6-36), sec. 1. For SEQ AF progress reports on service tests, 1938 - Amg. 1940, see AAF 400.112 Status of Service Tests Being Conducted by SEQAF, "Special File" (U). See also AAF 400.112 Fairfield Service Tests (March 1921-Sept. 1942) (U).



^{16.} Disposition elip. Brig. Sen. N. E. Gross to Col. S. F. Offin, 13 Sept. 1944. in Mas file "30.106 New Developments Division."

detachments normally consisted of two combat preve per airplane. 2 Meanwhile in the fell of 1939 the armement phases of service testing began to be shifted to Melin Field. Fig., and control shifted from the GER Air Force to the Air Corps Board and its resently-organised 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. Oscoda (Mish.), and others. By November 1939 the 22rd Gemposite Group was conducting its first armament tests there, involving the P-36D and I and the IP-37; and in August 1940 it began its first bombardment tests. Only armoment and air ordnance tests were under consideration when the site was originally selected. and even as late as May 1941, when Relin Field and the 23rd Composite Group were reorganized into the "Air Gorps Proving Ground, " the new directive defined the testing mission only in terms of "tactical tests of aircraft armament and its accessory squipment. " Furthermore, the appointment of one of the Material Division's top-ranking armoment officers (Col. Grandison Cardner) to head the organization in 1941 caphagized Eglin Field's armament

^{2.} Nemorandum for G/AAF by G/AC, 25 July 1941, in AAF 400.112 Tests and Experiments (U), (filed under 11 Sept. 1941). Exactly when service testing at Fatterson Field was abandoned is not known. Various proposals were made for retaining the work there, including a plan by J. M. Fials of the Maseriel Division in Aug. 1940. See RAR, Chief, MD, to Flans, 10 Aug. 1940, in AAF 400.112 Tests and Experiments (U).

^{3.} The discussion in this and fellowing paragraphs is summarised, except where otherwise noted, from data selected from Proving Ground Command Mistorical Branch, "Mistorical Outline of the Proving Ground Command" (Jan. 1945), especially pt. 1, pp. v, viii, 16, 20, 23, 31-32, 40, 64-65; and pt. 2, appendix A, exhibits 5, 6.

^{4.} Directive of 26 May 1941, in PGG, "Mistorical Outline ..."
(cited above), p. 39-40. Mimilarly on 15 Sept. 1941 the Air Corps Board issued a 16-page "Program of Accelerated Service Tests of Aircraft Armoment and Accessory Menipment." Copy in AFIEL and in AAF 400,112 Test, Development Work.

mission; and in general there was an awareness in the Air Gorps that amazent was the biggest gap in the testing program. At the same time, however, ever since Movember 1959, the 25rd Composite Group had undertaken some non-armament tests, and by the end of 1941 more than half of its projects were cutside the field of armament. Ultimately the more inclusive function covering all air material was acknowledged when the Proving Ground was reorganised into an AAF Command in April 1942. More than half of the nearly 1,500 test projects undertaken at Eglin Field between late 1959 and February 1945 have been concerned with the operational suitability of aircraft and of air equipment other than armament and ordinance.

^{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 speciality, "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. Gol. P. D. Carroll, Chief of EES) likewise dealt entirely with armament in "urging" such a Proving Ground in a study on 24 April 1941; and the Air Force Gembat Command (Brig. Gem. C. W. Enssell) concurred in the proposal on 12 July 1941. See Materiel Command has file on "CTI-190."

^{6.} Most of the 25rd 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 Antivated at Eglin Field (1939-28 Feb. 1945)", 2 vols., 142, 100 pp., in AFIHI. This valuable reference menual is a sumulative historical list of all PGC tests on airplanes and other nateriel, 1959-45, showing test number, title of test, completion date or other disposition; arranged according to category of materiel ar operational techniques; and supplemented by an exhaustive analytical index to specific materiel nomenclature, cooperating or other related agencies (e.g. Materiel Command, Havy, NDRC, British, manufacturers), and some tactical and other subjects.



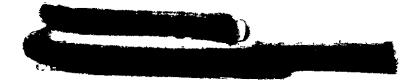
The wartime expansion of facilities for "eperational suitability" tests at Eglin Field was comparable in extent to the expansion at Wright Field. In October 1960 the field itself was vastly enlarged by the acquisition of the Choctawhatches Wational Forest adjoining Eglin Field, followed by the construction of special runways and several suxiliary fields and the building of special hangers, laboratories, and administrative buildings on the reservation. In terms of funds, the allotments to undertake this construction were as follows, by salendar years:

1941	\$4,742,936	
1942	8,428,769	
1943	2,456,300	_
1944	3,224,675 (to 30 Ju	ne only)

In addition to its facilities at Eglin Field, the Freving Grand Command was also given jurisdiction over the Gold Weather Test Detachment and its facilities at Ladd Field, Alaska, in August 1942; and a special climatic hanger at Eglin Field was under construction late in 1944. In October 1942 PSC detachments were also established at the Ordnance and Chemical Marfare proving grounds at Aberdeen (Md.), Edgewood (Md.), Jefferson (Madison, Ind.), and Southwestern (Hope, Ark.); and later, detachments were assigned to other similar installations.

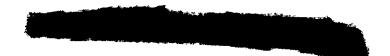
Still another group of service testing facilities established during the wer were those belonging to the tactical development organisations set up at Orlando, Fla., beginning in 1942. The Air Defense Board (about March 1942) and the School of Applied

^{10.} See "The Development of Pactics in the AAF" (AAF Mistorical Studies No. 13, July 1944, 107 pp.); and historics of the AAF Board and the Tactical Center, in preparation.



^{8.} A separate historical study on the facilities of the Freving Ground Commend is in preparation by the PCC Mistorical 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.



Tactics (Nevember 1962), reorganized in October 1963 as the Tactical Center, Il were all concerned primarily with developing tactical dectrines for the employment of aircraft and air weapons, but the operational testing of specific equipment was inevitable if operational dectrines were to be formulated effectively. While "material tests" at Orlando were not specifically authorized by any formal directive until June 1944, Is a large number of their projects was concerned with performance tests of equipment, chiefly equipment procured by Army supply services other than the AAF, Is such as the Signal Gerps, the Quartermaster Corps, and the Corps of Engineers. A metable early example of this notivity 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 werning and fighter control system intended for use in the North African landings that were to occur the following November. It

The testing activities at Orlando, together with the operational switchillty tests at Eglin Field, were all controlled by the AAF Beard in terms of jurisdiction between testing fields and priorities among projects; and the AAS Board was in turn subject to the staff supervision of AG/AS OCAR in Washington, 15 Daplication and overlapping between Eglin Field and Orlande were thme made more preventible; a further even 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 older, however. To remedy this, one of the elements of the plen for an Initial Pestvar Air Ferce, under consideration in April 1944, proposed that Wright Field's flight testing be merged into the Proving Ground Command. His doubted that such a shift sail ... sentribute to rapid and effective tests and propessed instead that the Flight Test Section be established as a separate command coordinate with the Proving Ground Command; that both be assigned as subordinate commands under Material jurisdiction; 15 and that the flight test organisetion, whose incilities were admittedly "imadequate," be "strongthoned" and perhaps moved to a "new base specifically for flight testing, "I" In the proposed AAP reorganization in October 1944, no disposition of the problem was made.

^{17.} Memorandam for Maj.Gam.O.P. Echels by Cal. J.F. Phillips, both is HMAD. 3 July 1944, in Mas file 30.109 Committee on AAF Development.



^{11.} AA* Reculations 20-14, 12 Mev. 1942; 14-A. 22 Dec. 1942; 20-14 B. 26 Feb. 1943; 20-14, 2 July 1943; 20-14, 8 Oct. 1943; 20-14 A. 12 Mev. 1943; 20-14 A. 30 Mer. 1944; and 20-14, 5 June 1944.

^{12.} ANY Reg. 20-14, 5 June 1944,

^{13.} AAF Reg. 20-14, 21 June 1944.

^{14. &}quot;The Development of Treties in the AAF" (AAF Historical Studies No. 18), pp. 40-42, 52-53.

^{15.} AAF Heg. 20-20. 26 April 1944.

^{16.} Memorandum for Chief, MB, by Col. R.C. Filson, both in MMAD, 15 April 1944, in MAS file #18,100 Miss.-Gem. #

The AAF and Cooperative Research, 1940-1944

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

Ordnance Department: bombs, rockets, guns, and assumition, as well as ground-force ordnance:

Chemical Warfare Service: special ordnance such as incendiary bombs; as well as ground-force items:

Signal Corps: radio and radar equipment, both air-force and groundforce items, until the transfer of air-related development to the AAF in Ogt. 1944;

Corps of Engineers: airfield construction equipment, crash trucks, etc.; as well as ground-force items;

Quartermaster Corps: air rations, flying elething, 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 WACA over the same period:

AAF	\$418,755,020
HACA	95,005,703
OBRD (including MDRC)	347,855,830
Signal Corps	158,808,378
Ordnance Department (Army)	172,775,914
Chemical Warfare Service	20,391,720
Corps of Engineers	84,612,072
Quartermaster Corps	2,946,586
Navy Bureau of Aeronautics	171,355,326
Navy Bureau of Ordnance	109,067,894
National Bureau of Standards	31,117,000
Civil Aeronautics Administration	8,247,628

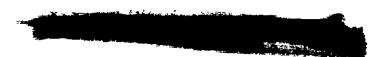
The research expenditures of most of these agencies covered more than air material projects, of course; in almost each case these figures also embraced ground force equipment, naval materiel, and equipment common to all the armed forces. Still other Federal research agencies contributed to the solution 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 \$600,000,000 annually for wartime research in the physical sciences, compared to only 250 millions spent in 1959 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 Mation'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

Agency	Total research expenditures	Rependitures within estab- lishment	Expenditures on industry contracts	Expenditures on university son- tracts
Army Air Porces	\$418,785,020	\$ 58,759,308	\$337,448,69 <u>0</u>	\$ 2,453,659
MACA	95,005,703	91,797,745	74,692	958,174
OSRD, including NDRC	347,855,830		110,046,850	220,816,521
Signal Corps	168,808,378	72,739,268	57,998,356	321,455
Ordnance Department	172,775,914	48,293,132	116,281,839	4
Chemical Warfare Serv	r. 20,391,720	16,544,741	2,834,820	
Corps of Engineers	34,612,072	8,391,821	9,079,308	
Quartermaster Corps	2,946,586	2,491,513	' m	184,580
Bureau of Aeronautics (Navy)	171,335,326	6,329,000	160,334,820	197,000
Bureau of Ordnance (Havy)	109,067,894		34,369,779	697,171
National Bureau of Standards	\$1,117,000	28,452,200		29,500
Civil Aeronautics Administration	3,247,628	886,148	489,148	205,800

Senate Committee on Military Affairs, The Government's Wartime Research and Development, 1940-44 (Subcommittee Report So. 5, 79 Cong., 1 sess.)



In the wast 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 YDEC 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 Havy Departments." The wording of this directive thus acknowledged the network of existing Army and Mavy 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 utilisation of industrial and university research facilities was far from complete. The origins of the MDRC can probably be traced to civilian scientists outside the Army (chiefly Bush, Compten, and Conent) rather than to any of the military agencies. In fact, the Air Corps, and prebably 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 seronautics, 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 soientific mobilisation than any other arm. This special air situation was recognized in the MDRC directive (quoted above), which specifically excluded the MACA and its "problems of flight" (aerodynamics, structures, and propulsion) from the work of the new committee.

^{4. 1}st ind. (AG 381 "Wational Defense" (5-11-40), 14 March 1940), C/AC to AG, Il April 1940, in AAF 400.112 Test, Development Work.



^{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 everhead within each agency (semetimes segregated), and funds transferred to ether Federal agencies or to State and local governments. For detailed breakdown by all these types of expenditures and by fiscal year, see Ibid., pp. 282-325.

^{2.} Except as otherwise noted later, the source for statements on the EDRC is ibid., pp. 216-226.

^{5.} Council of Mational Defense order, 27 June 1940, in Federal Register, 2 July 1940, p. 2445.

Once the MDRC was established, Air Corps headquarters saw in the new agency an opportunity to pursue scientific research on a number of non-meronautical 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 WDRC by the Air Corps: 5 of them in July and 20 in August, including the historically baffling question of bombing-through-overcast. Major B. W. Chidlaw, the newly appointed HDRC limison 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, ... Materiel Division." He further invited the NDRC scientists to visit Wright Field laboratories "at any time" and promised them the Material Division's "wholehearted scoperation."

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. O. Carroll and Capt. H. Z. Bogert suspected that MDRC 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 NDRG "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 meanwhile the WDRC ... will be taking a great deal of Wright Field time to bring a number of people up-to-date on what we have already done. " When WDRC officials "intimated" to Air Corps headquarters in November that Wright Field was withholding "complete information" in some cases, the Materiel 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 white House funds which are apparently not governed by the conventional time-consuming rules and regulations which generally are necessary in ... Army contracts." Furthermore, one MDRC activity, the microwave radar work at the Massachusetts Institute of Technology, was already showing results, Chidlew observed, "moving along in high gear and ...

^{5.} Maj. B. W. Chidlaw, MD, to Dr. Vannevar Bush, WDRC, 22 July 1940 (4 pp.) and 28 Aug. 1940 (11 pp.), and CTI-115, 18 Oct. 1940, all in AAF 400.112 Text, Development Work. Some of these projects were later shifted to the WACA.

Memorandum for Technical Executive, MD, by Carrell, 2 Nov. 1940, in AAF 400.112 MDRC (filed under 25 Nov. 1940)

^{7.} Memorandum for Technical Executive, WF, by Maj. E. M. Powers, MD, 25 Nov. 1940, in ibid.



ebtaining 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 semplaints that NDRC scientists were taking the time of Wright Field officers, Air Corps complaints arose in the other direction, that NDRC efficials did not wisit Wright Field enough, that they were inclined to remain in Washington and "occordinate" at long distance. The dependence of the AAF on the NDRC for certain of its non-seronautical research became se great that in September 1944 the AAF protested at the "premature" NDRC plans for demebilizing some of its projects at the end of the expected early collapse of Germany. The AAF, unlike the NDRC, planned "no sharp reduction of its research and development pregram"... until the defeat of Japan," and by the end of 1944 prepared to take over the more "promising" projects that the NDRC had sponsored.

The MDRC was a new agency in World War II, but not all of its procedures were new. In fact seme of them were not different from the Army's: the NDRC negotiated contracts with universities and industrial firms, much like the irmy did; they menitored 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 WDRC had no laboratories of its own for conducting independent research or for testing the results of its contractors; and MDRC's contractors were financed under "no profit no loss" contracts rather than under fixed-fee or percentage-fee provisions. Also unlike the Army, the NDRC and its subdivisions were composed almost entirely of civilian scientists temperarily 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 meronautical engineering and most of them comparing favorably with the equivalent technical personnel in industrial and academic institutions. The chief contribution of the NDRC 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 194111, and the impetus of additional accentiats, chiefly in universities, many of whom were not

^{8.} Memoransum for Col. O. P. Echols by Maj. B. W. Chidlew, 14 Dec. 1940, in ibid.

^{9.} Interview with Maj. Gen. O. P. Echols, 11 May 1945.

^{10.} Mas Materiel Division, diary, 2 Aug., 12, 21 Sept. 1944; Mas daily activity report, 9 Sept. 1944; all in AFIHI.

^{11.} The NDRC was supported entirely by White House funds in the FY 1941 (6.5 millions), but only partially so in 1942 (9 out of 32 millions). Other of its research funds during 1942, 1943, and 1944 came from Congress (238.1 millions), the War Department (50 millions), the Navy Department (54.4 millions), and the Lend Veese millions (4.5 millions)



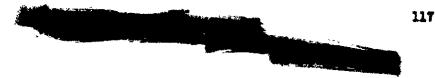
accustomed to dealing with the Army until they were mobilized by WDRC officials who "spoke the same language." Once the specific scientific projects were established by the NDRC and properly allocated among the available universities and firms, the AAF and other Army branches concerned assigned limison officers or project officers to follow the projects, and they received regular progress reports on each project. Mest of these projects, totalling 978 for the period from June 1940 to March 1944, represented problems submitted by the army and Mavy rather than problems begun independently by the MDRC. Of these projects, about 125 were sponsored by the LAF, and 500 by the other supply services of the Army Service Forces, the latter including of course many of primary interest to the ALF. By December 1944 the Army's active projects with the HDRC totalled 299, including 79 for the AAF and 220 for the ASF, the latter including 32 sponsored by the Signal Corps for the AAF before the Signal Corps air functions were transferred (in Oct. 1944) to the AAF.

Among the other research agencies was the Havy Bureau of Aeronautics, which had its experimental establishments at Philadelphia and Paturent, Md., providing still another source of research and development for the AAF. Unlike the ASF and the MDRC, the Mavy's relationship toward the AAF was, of sourse, competitive. Both of their material centers were developing many items of aircraft, engines, armament, bombing equipment, and other apparatus that were similar if not identical as to their tactical requirements and uses. Aside from the Mavy's special equipment for carrier-based sircraft, most of its equipment was, after all, common to military and naval seronautics. 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, 13 and the two research and development programs were frequently rationalised 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 "bogey of duplication" in mientific 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 limison officer at the MACA, as follows: "Almost all /scientific findings, concepts, and opinions ... are contreversial"; 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 scrutinise and disagree with each other's work is as valuable in achieving scientific progress as is freedom of speech in forming public opinion. "14

^{12.} RAR, MD to MAS, 5 Dec. 1944, in AAF 334 Boards, Misc.

^{15.} R&R, Supply Division to Col. Carl Spantz, 29 July 1939, in AAF 400.112 Tests and Experiments (U).

^{14.} Memorandum by Greene, 30 June 1944, in AAF 360.2 Development and Research (filed under 11 July 1944).



Whether this theory was also a fact, as between the Army and the Mavy, 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 terpedo (Mavy), the dive bamber (Mavy), and the heavy and medium bombers (Army) were cited as examples of "progress that might not have been realized from a single air force." 15

Whatever the merit of these claims (and each of the specific examples might be debated), the two experimental establishments did not setually work entirely independently of each other. Joint consultation between them was common, including periodic reviews of their research and development programs, in 1959 as in 1944; joint conference, in MAGA committee deliberations, a standard procedure that dated back to the very beginnings of the NACA in 1915; and the system of limited officers exchanged by the two material centers, a practice that began apparently in 1939. The Mavy was probably more aggressive than the AAF in pursuing this limited. Thus, the AAF had only a single full—time officer with the Eureau of Aeronautics (Col. John H. Sams) and while his reports on Mavy developments were frequent and informative, 17 MMAD and Wright Field were "frequently ... criticized for lack of limited."

MMAD and Wright Field were "frequently ... criticized for lack of limited."



^{15.} Memorandum for C/AAF by Rear Admiral J. H. Towers, Buser, 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 Memos, Numbered (U).

^{17.} HMAD Materiel Division, diary, 2 June 1944, in AFIHI.

^{18.} Some of Same: reports are in AAF 380 Programs and Projects (20 May, 20 June, 24 Nov. 1944), 360.2 Development and Research (12 Oct. 1944), and coc.71 Interviews (50 Sept. 1944).

The Navy, on the other hand, carefully attended most AAF mook-up inspections and tests; stationed over a desen permanent officers at practically all of the laboratories and units at Wright Field, provoking one comment that every AAF project officer had a Navy efficer 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 senter.

The AAF was opposed to formalizing this cellaboration with the Havy to the extent of throwing its research and development program together with the Eavy's into a committee that might tend to reneve the AAF from direct control over its own material activities. Thus in 1940 the Mavy suggested that very precedure—a proposed joint subcommittee of the MACA -- and was suclded by the Air Corps for abdicating, in effect, its basic responsibility for military requirements and tactical evaluations: the irmy and Havy "should /not" admit that the pressure of business makes it necessary to transfer to a third agency /the job of 7 coordination between us"; the existing Army-Mavy lisisen system som keep the two programs integrated without entside non-military helps; it is the tactical requirements, known only to the army and the Mavy, rather than technical limitations or scientific frontiers (the province of the NACA) that must determine the projects and priorities of the research and development progrems; and, finally, the Mavy proposal "would place in the hands of the NACA a soutrol over naval and military experimentation never intended by the acts establishing and empowering the MACA with aviation experimental authority and ... not ... to the best interests of our two services ... 20

Nor was any other permanent or ad hos wartime committee appointed to control the Army and Mavy 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 1943, but it was more a device to bring the civilian head of the MDRC (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 Buser General Representative at WF, 23 Aug. 1944, in ATSC 045.2 Mavy (U).

^{20.} Memorandum for Rear Agmiral J. H. Tewers, Buser, 25 and 26 Oct. 1940 (grafts), in AAF 400112 Tests and Experiments (U).

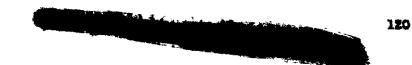
Within the War Department, the AAP's growing autonomy after 1939 had repercussions on its research and development program. The General Staff, which had earlier in the past two decades adversely affected (for example) the development of the heavy bomber, had no appreciable influence on the development program after 1939. U-4 had no representation on the Kilner Board in 1939, and only a junior officer on the Ermons Board in 1940. In August 1940 G-4 was given staff control over all "defense projects" throughout the War Department, including development, procurement, and supply of material, 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 preserve and development] agencies throughout the War Dopartment. Homewor, the correspondence and other records of G-4 reweal little concern or interference with the nAF program by higher authority after 1940. - Soon General brooks, Chief of the Air Gorpe, 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 Jorps research and development program by making 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 Far Department?" and Maj. Con. G. H. Brett, the new C/AC, ordered the Material Division to "file away and forget" the General Staff request. 23 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 rigarmarole 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, 25 essentially the responsance 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, 26

22. See C-4 case files, and index to them, 1921-43, in ACC War Department Records Branch.

24. Inter-deak Memorandum, Lt. Col. S. W. Chidles to Brig. Com. J.P. Echols,

^{21.} AG 320.2 (7-29-40), 6 Aug. 1940, "Defense Projects," in AAF 380-381-381.4 Mational Defense; and AG 320.2 (9-10-40), 14 Sept. 1940, "Goordination of Research and Development...," in AAF 400.112 Tests and Experiments (U).

^{23.} AG 400.114 (1-13-41), 5 Feb. 1941; memoranaum for Col. Orlando Ward, Secretary of NDGS, by Arnold, 11 Feb. 1941; and notation by Brett to Brig. Gen. C.P. Schole, 19 Feb. 1941; all in MAS Development Engineering Branch file on "1941 FY R&D Program."



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 Mavy 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 measures 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 Freduction Beard, for example, there arese in June 1942 a proposal for a WPB Office of Teennological Development, to "utilise 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 objectious were registered through the WPB Aircraft Branch which echoed, in effect, the opposition of the AAP. W J. Augustime of that Branch opposed the move as (1) shear 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 Mational 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."27 An expansion of this proposal came to the attention of Materiel Command headquarters in September 1342, when a WPB employee-a "Senior Program Procedure Analyst (whatever that is)"

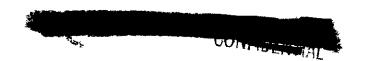
came wandering into my /Col. B. W. Chidlaw's/ office one afternoon and started to ask a lot of rather vague and disconnected questions as to how we handled development problems, how we maintained liaison with outside research agencies, how we did this and that, etc; ... it was quite apparent from the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

^{26.} Memorandum for Director, MDD, by S/W, 18 Oct. 1948 (copy), in MAS Dewelopment Engineering Branch file "80.105 MDD"; and MD General Council



^{24. (}cont) 8 July 1941, in M&S Development Engineering Branch file "1942 FY R&D Program."

^{25.} WD Circular 555, 15 Aug. 1945.



The WPB employee left a draft of the proposed directive with Chidlew, and when General Echols 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 /acronautical development/ is to set up another Bureau in Washington to smother it with committees, programs, meetings, priorities, and directives"; and the WPB's new preregative would permit the WPB to "direct" research and development, to "centrol the time /the moment of standardisation/ 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." 28

The War Froduction Board proposal, which was not widely publicised. was shortly withdrawn by Donald Helson, WPB chairman, due to the interwention of the Under S_cretary, but meanwhile a similar proposal was placed before the Senate by Senator Harley M. Kilgore. The directive of his proposed Office of Technological Mobilization, embedded in bill 5. 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 emstional and less ressonable 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 beings. "29 In fact, some of their arguments, that the new OTM would impose centralized control over science, contradicted some of the igny arguments, that the OTH would result in divided and conflicting soutrels. On the other hand, a few advecates 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

^{29.} Statements reprinted in Science, 7 May 1943, pp. 407-412, 486-487; 14 May 1943, pp. 438-439, 442-443, 510-511; and 4 June 1943, pp. 508-509; and Journal of Applied Physics, May 1943, vol. 14, p. 203; and July 1943, vol. 14, p. 511.



^{26. (}cont) minutes, 22 Peb. 1945, p. 1, 25 Oct. 1943, p. 1, and enclosure "A", and I Mov. 1945, p. 8, all in AAF 55? Conferences, "Bulk" files.

^{27.} Transcript of WPB hearing, prepared "for record" by W.J.Augustine, 5 June 1942, and sent to Chidlaw, 20 Oct. 1942; in MAE Development Engineering file "700.430 Kilgore ...".

^{25. &}quot;Informal" memorandum by Chidlaw, "Back history" of Senator Kilgore's proposal for an Office of Technological Mobilization, 10 Oct. 1942; and memo for US/W by Echols, 26 Sept. 1942; both in MAS Development Engineering Branch file "700.450 Kilgore ...".

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few other industrial executives, ⁵⁰ Dr. Vannever Bush, the director of the Office of Scientific Research and Development (including the MDRC), whose position was of sourse threatened by the bill, agreed that wartime "centralized control" was necessary but argued that this was already being accomplished through the MDRC'S "finely meshed machinery" of Army-Navy-civil scientific relations. ⁵¹

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 "scoperation"; "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 organization) 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 specialised personnel available in seronautics 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 Materiel Command, the Bureau of Aeronautics, the HACA, and the aeronautical industries in general. ... unless the Technological Mobilization Corporation took ever 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.

^{32. &}quot;Informal memo" for Brig. Gen. B. E. Meyers, by Col. B. W. Chidlew, 10 Oct. 1942, and "memo report for record" by Chidlew, 12 Oct. 1942, both in MAS Development Engineering Branch file "700.480 Kilgers ..."



^{30.} Hearings ... S. 2721, Oct-Dec. 1942, before the Kilgore Committee, especially pp. 215-222, 234, 509, 515; and New York Times editorial, undated, about May 1945, reprinted in Science, 28 May 1945, p. 488.

^{51.} Bush to Kilgore, various public letters, reprinted or summarised in Science, 31 Dec. 1945, pp. 572-577.

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The Kilgers proposal eventually empired, after being revived in 1945 and 1944 in other forms. AAF control over its own development program was probably never seriously threatened; and exide from the burden on the AAF in marshalling date 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 $^{\mathrm{1}}$

The progress of meronautical research in England is closely connected with the advances made by British science in reneral. Scientific achievements in 17th century England were riorious, but during the 13th 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. Thile 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 bestief 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 hed 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, ArIHI, April 1945.

remained more "research conscious" than ever before, but smaller firms had a tendency, probably for financial reasons as much as any other, to stick to old and out-moded nethods. 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 southt to open up new channels to the sources of research by scholarships, and by special grants for investigation. Chemical Industries, td., led the way, and other corporations soon followed. By 1937, the repartment of Scientific and Industrial Research was able to spend = 372,127, and maintained eight special research establishments well provided with sore thirty boards and committees, and maintaining close contacts with twenty industrial research associations, 3 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 scicntific investigation themselves, the numerous scientific and professional societies perform the highly necessary work of coordinating much of the research is 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 mited States or the Joviet Union. According to one estimate, 1/10 of 1% of the British national Income is spent on scientific research, while approximately 5/10 of 1% is spent in America, and 8/10 of 1% in the Soviet Union. 4 "It is essential to bring home this capital deficiency of Tritish science, the fact that its total development in relation to national needs is grossly inadequate."

In 1937, a total of & 3,230,000 was spent by the reversment on scientz ific research. Some of the larger expenditures were allocated as follows:

Fighting services	1,536,000
Tent, of Scientific & Ind. Research	533,000
Ministry of Agric, and Fisheries	469,000
ielical Research Council	195,000

The Penerthent of Scientific and Industrial research gave & 105,5% to the National Physical aboratory, and short some & 126,510 in grants to research associations; the remainder of its budget went to chemical and agricultural projects. The flighting services have & 727,500 to the RAF, & 416,500 to the Wavy, and & 391,500 to the Army for research and development.

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

^{2. *}Research - A dational Resource", Jection II, Industrial Research. (Wational Resources Planning Board, 1940)

^{4.} Java Bernal, The Social Function of Science, 63-4

^{5.} Ibid, 65

^{6.} Ibid. 422

^{7,} Ibid, 427

in shyland did not occur until 1905, interest in the possibility of aeronautics had existed for a long time previous, and had expressed itself in merostation or glider experiments. When Colonel J. C. Capper became head of the government balloon factory at South Farnborough, he wade this factory a center for seroplane experiments and investigations that paved the way for A. V. Roe's first flight in 1908.

'a carly as 1904, Broyet Colonel J. D. Fillerton of the Royal Engineers had suggested that a committee composed of scientists, or theory, and naval representatives right undertake the scientific investigation of aeronautical techniques. However, the yvernment 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 Correction of Imporial Defense had advised that the mirriane experiments being conducted at the balloon factory at Paraborough be dropped, and when, by '909, two experimental planes had consumed a total of & 2,500, the government decided that the results did not marrant such an o tlay 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 harmoned, Britain could catch up if necessary. R. D. Taldene, the War Secretary, well expressed the national feeling toward aircraft in a speech delivered in 1910.

When 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 hirself 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 noncomer 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 Islas. Furthermore, there was a perfectly natural desire to protect the national investment in the Royal Mavy, and a hesitation to rush into the development of a meanon, that might render sea nower obsolescent. According to an official report,

. . . up t the end of 1911, the policy of the Soverment with regard to all branches of norial navication was based on a desire to keen in tough 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 Trights' invention when it was offered to them.

^{8.} Raleigh, Kalter, The Nar in the ir, I, 153-9

^{9.} Ibid, I, 157 10. Ibid, I, 75 11. Ibid, I, 3

Nevertheless, Colonel Fullerton's surgestion was not entirely discregarded. 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 Frime 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 cest 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-siveraft. 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 records, and owned a plant consisting of rany 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 rovernment 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 trads.

^{12. &}lt;u>Poid.</u>, I, 160-2

^{13. &}lt;u>Ibid</u>., I, 5

^{14.} Ibid.

^{15. &}lt;u>Ibid</u>., 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 500,000 drawings to firms hitherto unfamiliar with plane manufacture.

Meanwhile, the Toyal Flying Gorps came into being in 1912 with its Military and Tayal Wings, and to coordinate these two branches, an Air Committee was set up in July of the same year. The Haval Wing was under the control of a Waval Air Department commanded by Captain Murray Sueter. 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 gumnery, 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 on 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 organisation. However, in comparison with the other great powers of Europe, British acromatical 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 chances 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 spitable 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

^{16.} Journal of Applied Physics, Aug. 1943, P. 399.

Committee on heronauties, British aviation during the war was e-usiderably handicapped by the lack of a stitable motor, 17

In 1920, the idvisory Conmittee was renamed the Aeronautical lesearch Committee, and its functions were considerably expanded. Sub-committees were set up for accidents, air inventions, aerodynamics, on ines, meteorotory, and swimtion. The functions of the Committee were defined as follows: (1) to advise the Lin Decretary on scientific problems; (2) to make renormendations for, and to initiate research; and (3) to supervise aeronautical research at the Vational Physical Laboratory. Through its activities, the conmittee has made important contributions in the following fields of her satisfal investigation; (1) scale effect, (2) stability and control of science; (3) auto-rotation and scinning, (4) flutter, (5) air-foil theory, (6) motion of the surface layer, (7) resistance, turbulence, and streamline motion, and (6) airflow at somic species.

I'm Co wittee also lent in close the brith the other areacles interested in a repression research. Through the Air Simistry and the Director of scientific and Industrial Research, it was able to coordinate its work with the studies being undertaken at the various hir Vinistry Experimental Establishments. Through its contects with the Society of British Aircraft Constructors it was requalited with the needs of civil aviation, and was frequently used by the sir Ministry to distribute manusalment to individual researchers.

stween 1920 and 1939, the National Physical Paboratory's Decartment of Accodynamics worked on various relation problems. Although biplane stability problems were fairly relating inderstood by row, the same cannot be said for the morphlane. When the shift to this type of plane occurred, the Intianal approaching made a special point of studying monoplane stability, and we are red in this research at the outbreak of the war in 1939. During this period, the APD worked in close contact with the distinguished physicist, Professor 3. I. Taylor of Carbridge. Close attention was also paid to the research of recessors Francti and you Farran in Germany. 20

the the directorate of because and rised it under the lenarte was made in the research set-up. However, in the 1920's changes were made in the time of coordinating and intermiting the functions of the different agencies. If the time wer, research had been assimed to a directorate of the time to mell known as the fechnical Department. However, the Royal Associated Cociety felt that the arrangement was not favorable to the study of basic flight problems, as at their undirect the time council of the similarry set up a new firectorate of besearch and risced it under the lenartment of Supriry and Receased, 21

^{17,} Johns, The Par in the Air, III, 253-5

^{1&}quot; "Puture of the feronautical "escarch Committee", Plicht, 6 %, 1 120; also Mazebrook, Sir R. 3., "Acronautical Research in England", paper road at 4th IAC, Rome 24-36 Get 27

^{10.} Timberis, T.E. The Progress of Aeronautical Tesearch in H. Eritain's maper read at 4th 100. Rome, 74-30 at 27 NACA Lib.

^{20,} old, 5. I., "Aerodynamic escarch at the Will, paper read at los nyeles continy of the IA3, 30 Jept 3", MCA Tib.

^{21.} Aircraft Engineering, Var 35, VII, No. 75, p. 105

However, in time this arrangement was criticized on the grounds that the head of this department was too much involved with sundy to devote himself adequately to research. In 1935 the duties of the Suply and Research Section of the dir Duncil were split in two: there was now to be one maker for Tesearch and Sevelopment, and one maker for Supply and Organization. Under Research and Development were placed the Directors of Technical Development, Scientific Research, and Aeronautical Inspection. Special mention should be under of the Director of Scientific Research as he exercised a supervisor control over the "in timistry's Experimental Establishments. These so sinter if the pefore-tentioned plants at Aartle-shar for land Aircraft, and at Felinstors for sea clames, and the Air Ministry Laboratory at acut tensington for pursical and chemical research. Thus, research functions were taken out of singly and given to a member of the dir Sourcil who was to be able to Levote full time to there. 22

Civil aviation research, with potential value for military aviation as rell, as stipulated of overmental subsidies or opecial grants. For the year ending 31 March 1933, the poverament also the following grants to assist civil aviation:

For a nominal fee, the National Physical Laboratory was available for special research for any of the private permutical concerns. As previously indicated, in 1937, the poverment made it 1,536,000 available to the fighting services for seronautical research. The

While government subsidies to the air injustry have usually been welcomed, there has been some prosition to the amounts spant on research—small as they were. G. G. Grey, ardent adulter of Nazi Germany and editor of the influential magazine, The leronlane, violently attacked all of the efforts of British cabinets to centralize and coordinate aeronautical research in the 1/2)'s and 1730's. Much of his ire was reserved for the farmborough Establishment and the \$400,000 a year which the covernment expended upon it. Typical of the editorials which appeared in The Aeroplane is this except from the editorial page of the issue of 12 February 1736. Quoting Charles V. Allen of the Society of British Aircraft Constructors, Grey 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. Grey), our I 400,000 a year for Farmorough 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.

^{23.} Report covering aviation laws, regulations and policies in England, France, Italy, Lapan, and Bussia. A-2 Lib.

^{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 Jecond Torld War finally brought about a complete reorganization of research agencies. In May 1940 a Pinistry 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, a 26 Aeronautical research, therefore, was now a part of this new limistry, and no longer a responsibility of the Air inlutry.

In the Ministry of Aircraft Production, research was placed under a Controller of Pessarch and Development, and a Controller of Communication Equipment. The Controller of Research was responsible for scientific investigation connected with all airborne equiment, (excluding items like radar and radio which were the remonsibility of the Director of Communication Equipment), used by the RAF, Navy, and civil aircraft being manufactured under the Binistry of Aircraft Production. 27 To insure the proper distribution of research projects, as well as the conservation of effort for major projects, there was a Directors desearch and Development Committee meeting twice monthly. It consisted of the principal directorates in the Department of essarch and levelo ment, and was advised by Technical Advisory Panels composed of the senior representatives of the nine Experimental Satablishments and the headquarters directorates concerned.

The Perartment of R & 7 was divided into directorates as follows: Scientific wegearch, (2) Technical Development, (3) Engine Sevelopment, (4) Armoment Vevelorment, and (5) Communication Development. The responsibilities of the Director of Jeientific Research were especially great. He was to see that the necessary scientific work was done, and amplied in immediate development, and therefore he had a certain supervisory control over the futallishments of certain departments at the NP... He was also responsible for the assignment of a pool of scientists maintained by the Ministry of Aircreft 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 RAF commands. 27

The Director of Technical Development was responsible for the airframe of Pritish 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 Degine 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 Kinistry of Aircraft Production totaled about 5,800 persons, of which approximately 94 per cent were civilian. 30

malands, i., "The work of the 'inistry of mireraft Production," Firther, Jent 12

^{27.} Fillitary Attache Report, No. "2979" (n.d.) 4-2 1b.

^{27.} Ibid.

^{29. &}lt;u>Told.</u> 30. <u>Told.</u>

Naturally, the mor' of the Royal Aircraft Establishment was entirely concentrated on var problems. The work was usually of a long-term nature involving projects taking more than 12 months. It was estimated that at least 70% of the tests and studies had an immediate practical application. Investigations covered such fields as aerodynamics, engines, radio, instruments, photography, aircraft structures, evangent, 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 "ir Force, but also for the Army, the Fleet Air Arm of the Royal Mavy, and civil aviation." 32 However, there is likely to be much opposition to this plan from the older services, and at present it is impossible to may just what sort of research organizations will be maintained in England after the war.

In conclusion, it may be said that mer mautical research in England has suffered from some of the general problems of British scientific investigation. There seems to have been a certain slowness on the part of corporations to recognize the value of industrial laboratories, and, as pointed out earlier, science in Ingland is poorly supplied with rowey especially when compared to the generous outlays which are provided by the American and Boviet 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 Hingdom. 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 Rational 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 MPL or ld readily be translated into prototypes. In the opinion of Air Vice-Parshal 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."

^{31. &}lt;u>Ibid</u>. 32. <u>Ibid</u>.

^{33.} Jones, The har in the hir, III, 259

Also praiseworthy is the close connection maintained by the Air Finistry with the Tational Physical aboratory, and the Aeronautical Research Committee. Under this set-up, it is a comparatively simple matter to study the mobilers of aeronautical research, institute the appropriate scientific investigation, and then, through the medium of the Rill, apply the new discoveries in practical experiments and test flights with full size workin; nodels. This slose union of theory and practice is one of the most satisfactory procedures in ritish aeronautical research today, and will doubtless be maintained in the coming years.

Part D

STABLE N. F. JOP NT IT GIVEN, 1914-1939 1

Thetever the outco e of the current war, there can be no denying that deriving engineers and scientists were first in the mir with several fundamental reaches, and of the five missiles and pickes driven by recent and jet promision. Although it is probable that the pressure of war forced a preseture commitment of these impoyations, order to their scheduled development, nevertheless they have usen sufficiently destructive to cause the illies considerable and reheasion. In virtie of the relatively limited resources of the German pressure state as compared with those of the Soviet Union on the United States, it is northness to raise the question as to have any of the Jermans were able to create these weapons before the Allied research Imporatories could brise them into operation.

The normans are several, one of ther is to be found in a remark attributed to the Prussian him; whose country was heared in by the armica of 'amolenna " "We mu t make juod with our rinds what we lack in physical reso rees." Germany did ma'e good with her minds what she lacked in resources. In the mineteenth century her universities proceeded to foster research in scientific fields while elsewhere a certain academic anobbery kent science from "contaminating" the university until a late date. Her scientists, covernments, and industrialists had initiated the establishment of research schools, research institutes, and the publication of specialised scientific journals long before these were com on elsewhere. Perhaps the greatest advants wor Corman actores was its association with the tradition of German learning, also the mest prestite accruin to the scientist by wirtue of official recomition for his achievements. He was an important and Middly respected member of the national and local community. In France, Comland, and in the inite: States, he had no fight for this recomition: in fact i' is doubtful wither in the laited States he ever has achieved the public esteem lost ago granted him in Jermany.

The retience and precision of the Jerman researcher became proverbial. To had an interac curiosity to other with right is best described as an "appreciation of a patient and exact determination of the structure of the world, the belief in the Lithinsic value of sure scientific truth." I with this rental approach and equipment, with a high degree of state and community appreciation, the real advantage of Jerman science came in the last quarter of the nineteenth century, after the industrial revolution had arrived in force. Serman industrialists proceeded to accept the theoretical scientist, which is now than could be said if r their contemporaries in ingland and the united States. Thereas the "practical" business man in the latter two

^{1.} Prepared by Cent. . Tw Nohfledschy & TII, April 1945.

^{2.} Quoted in t. Y. larts orne, "The Berman Universities and the Government," in the Annals of the American Academy of Political and Social Science, Vol. 200, ov. 1938, 232.

^{3.} J. F. bernal, The Social Tunction of pelence, (London, 1939), 212.

countries tended either to despise, or at lest to impore the mere theoretical scientist, in Jermany the industrialists bustoned to ally themselves with and to make use of the theoreticism. 4 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 dermany 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 impland or the inited States. But there was not enough opposition within military circles to prevent the derman 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 bellimerents, 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 Joubt for a time.

ifter Norld har I, German science reached its apex. The state long had supported science with an effectively organized teaching 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, Germany led the way in organized research. It is estimated that in 1930, 10 willish Reichsmarks were scent upon research by the leich government, while the state covernments contributed approximately 20 millions more, all exclusive of willter; research. And this was norm than Britain was spending. When the estimated amounts being scent in industrial research were added to this figure the total became something like 50 her cent more than English expenditures for research, viewed in terms of the discrepancy in national income.

Perhaps even more important that 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 "orld War I in the creation of the raiser Wilhelm Society's

6. J. J. Bernal, The Social Munction of Mience, 19:1-200.

^{4.} Ibid. The operabrium heaced upon the so-celled "Brain Trust" in the United States very probably is based upon something more fundamental than more disa-research in politics. It is a nice illustration of the basic distruct on the part of the practical business man for the so-celled impractical man of theory, although in this case most of the criticism was lirected towar the social scientist. It is significant that no effort was made to distinguish between the practitioners of social sciences and natural sciences. "One too that the popular comic strips continue to deplet the professors as "Prof. Tuste."

^{5.} It is claimed that the lermans killed two men for every man they lost; for every Jerman aircraft lost, six energy planes were destroyed.

<u>Ibilar 172</u>. These claims bear matching a ginst Allied figures, particularly for the war in the mir.

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 eq ipped in a way which no university could approach. Furthermore, the staffs on not forced to rely upon immuture researchers fresh from the training schools. Instead they attracted scientists of international regule who were expected to devote only mant 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. Then powered flight first presented its technical problems in the years prior to World War I, there was at hand a solid body of basicwork in mathematics, physics, chemistry, and engineering upon which to draw. In the applied fields there was available a substantial body of information on the attength of materials, durability, and fatious. It was not necessary to start from scratch. But various other types of information necessary for aviation never had been leveloped in detail, simply because other technics had not needed them. There you 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 measure of a series of fatal accidents and the knowledge that other countries were entering upon mascent programs of investigation in the field of aviation. Eut more important there was the initiative of the Kaiser, his brother, Prince lenry, and of Count Zeppelin, strongly supported by the Chancellor and the Prussian Minister of the Interior.

As early as 1909 Count Zeppelin stressed to the German Nuseum at Nunich the necessity for aeronautical research organization; in the same month the Maiser, as fine of Prussia, commanded the Prussian universities and technical institutions to do more for aviation. By December 1909 the idea reached the Reichsta for the first time when a group of representatives presented a measure seeking the establishment of a modernly equipped research institute for lighter-than-air work at Friedbrichshafen, under Count Zeppelin. Length debates easued in 1910 and 1911 as to the proper location, for Berlin was the choice of the Frussian for linistry because of its central location with respect to the entire country, and both the site on the Bodensee and that at Frankfurt a/m were forced to yield to Berlin.

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

^{7.} Friedrich Seewald, "Fie Auf aben und Arbeiten der DVI in Rahmen der technischen Forsehungen," in Zeitschrift des Vereines Jeutschen Ingenteure, Bd. 81, Nr. 17, 24 Apr. 1937, 471.

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 faiser 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 Derman research institute ministrate to the French as urgently necessary.

On 20 April 1712 the research institute was founded at Adlershof, one of Berlin's suburbs. The new <u>Pautache Versuchsanstalt fur Luftfahrt</u> (DVL) thus became the focal point for the aviation interests of Germany. As founders, there were representatives of the Heich Ministry of the Interior, the Prussian Har Ministry, the Scoretary-General of the Kaiser Wilhelm Scolety for the Advancement of Science, the Jociety of German Engineers, and a substantial list of names representing the larger firms in German industry. To the first administrative council of TVL came men whose names and products already were known over the world, among them, Benz & Cie, Opel, Sperling, Adolf Painler, and Hobert 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 atreased that the advancement of swiation would occur through scientific and methodical investigation, that there must be a narrow and close ecoperation between the DYL on the one hand and the universities, technical high schools, and state testing offices on the other. If One additional point should be considered. In the final discussion over the establishment of DYL 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 Tyll 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 anounced to 5,000 "tarks."

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. Basumker, "Die Peutsche Versuchsantalt für Liftfahrt in Rahmen der deutschen uftfahrtforschung," in Zeitschrift des Vereines Deutschen Ingenieurs (VII), Bd. S1, Br. 17, 24 pr. 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. Basumker, "25 Jahrs FVL," 98. In this connection it should be stressed that the German <u>Technische Hoddschulen</u> are much nore advanced than any inerican high school. Those at Aachen and Berlin, for example, would rank more as advanced engineering institutes than as high schools in the American sense.

^{11.} Ibid: "Die Deutsche Versuchenstelt für Luftfahrt," in Die Luftmacht. Heft. 11. Nov. 1927, 635. Pirat director was Dr. Bendemann and one of the first associates was Fr. Ing. Wilhelm Woff, later a long-time director of the Institute.

which involved the proof and testing of 65 mators within a year. Then in the fall 1913 care the first threat to its sphere of competence when the military annumed its intention of establishing a special military research institute for aviation at Poberits. I mediately the director of DVT. Sirected a memo to the Binistry 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 organisation, apparently acting on the defense against some military leaders, who had determined to set up their own institute. 12 Here for the first time in the history of Jerman aviation technique appeared a sharp class cettern 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 2' February 1914, the binister of the Interior inferred CVI that the Crussian far Inister sould establish a close connection between the technical testing committees and IV: the test results in the field of filitary Aviation would be made available to Adkershof. The position of IVL was thus fixed as a hundraiden of the buftwaffe.

VL was not the only research institute in existence prior to the war. As early as 1907 Fr. Judwig Frankil, the University of Sottinger, constructed the first wind tunnel in Sermany and by 1912 the aerodynamical laboratories at Gottingen and the <u>Technische Moschschule</u> at Aachen both were well established. But it was the task of IVI. to draw to gether the work of all of these Institutes.

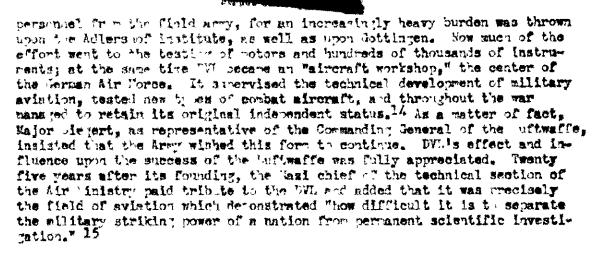
Forld Far I

By the eve of forld ar I the formed government had short approximately 132,000,000 on ammountical research, a sum more than 10 times that spent by the British and better than 60 times the United States expenditure. The forest hit of those who had brought PM into existence two years earlier was more than justified. The institute possessed some 70 workers, it had several motor testing stands, an electrically driven probabler testing installation, a wind tunnel of 76 cm. Simmeter 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. You the task jumped enormously.

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

^{12.} A. The mker, "25 Jahrs DVL," 77. A marently this was a recurrence of the old struyte between the "practical" military men and the "theoretical" scientists.

^{13. /.} Tamankem, "Die Deutsche Tempuchsanstalt für uftfahrt in Rahmen Jer deutschen Tuftfahrtforsening," 469.



Pefest brought an end to the intense activity of DVL. In 1913 it still had some 100 personnel, of show il were scientific engineers. But by 1922 the total had dropped to 15, only two of whom were engineers. The Versailles treaty had cut lerman aviation effort to a very low point, nevertheless the MICA representative, visiting the country in the spring of 1920, mined an impression that despite defeat, the lermans firmly pelieved in the future of con ereial existion. Sessarch never did cease altogether. Down at Gottinger Prof. Prandtl and his assistants in Albert Bets and In. Carl Wieselsberger had a new wind tunnel of 2 meters diameter which was described by an MCI representative as the Wilnest arrangement I have seen so far in any wind tunnel, including—England. Already in 1923 there was talk of constructing a new SVL, but funds were shirt. For till 1922 was there a nermanent fund for the institute in the Leich budget, and from this time on the director of DV. no longer was forced to justify his needs quite so carefully.

Veanwhile the work of investigation proceeded at Sottingen and at Aachen. Francti at Sottingen had one such exceedingly laborious work in the mathematics of the motion of a more sible fluids; his theory of the boundary layers was widely known. By 1921 Theodor won Karman at Aachen presented a simplified momentum theorem for the boundary layer, and the Aerodynamic Institute of the Technische Hoschschule at Aachen became one of the leading aeronautical research centers of Sermany, along with Sottingen.

Turn that the rost-war period prior to 1933, there persisted a shortage

(maner in NACA Intell. Lib.)

^{14. &}quot;Tie Leutsche Vorsuchsanstalt für 'uftfahrt," in <u>Lie 'uftwacht,</u> left li. Tow. 1927, 635-636; & Baeunker, "25 Jahre 'VL", 100.

^{15.} Told; A. Facusker, Tie Deutsche Versuchsanstalt für Luftfahrt in Rahmen der deutschen uftfahrtforschung. 470.

^{16.} But and all aviation lenders appreciated DVL. Er. Doraier, for example, is reported to have belittled it; Juniers, on the other hand appreciated its value and took his problems to Adlershof. E. T. Allen, "New Wings for Germany," In Aviation, Feb. 1936, 24.

^{17. &}quot;Tilliam night, "Visit to Jernany," 27 way 1920, in NACA Intell. Lib; J. "acoll, "Rodern Aerodynatical escarch in Jernany." 6 Feb. 1930,

of funds; furthermore the meichstay displayed only a limited interest in swintion. At DV the reduced number of personnel carried on while slowly the institute regained its strength. By 1925 it had a force of 100; two years Inter this had nearly tripled, reaching 285. In the latter year 12 million marks were earmarked for an expansion program but the project was delayed cending a selection of the site. It was difficult to convince the Meichstay of the long term value of the research institute but the need increased and so messing was the lack of equipment that finally it was norten material that specific research by blems should be farmed out to the inited States which possessed more adequate facilities.

Throughout this period, IVI. maintoined its close relations with indictry and the technical institutions, particularly Jottingen and Aachen. EV. did not duplicate their work. Instead it tried to systematize their research and oring them to encentrate on the more important problems. Then too much of its work consisted in testing new inventions. 19 By 1931 IVI was the examining institution of Jerman aeronautics, acting under the authority of the Jerman Transport Law (merial). Its jurisdiction included the certifying of types, examination of construction and design, and subsequent revision of licensed aeronautical construction. 20

Although 'V', was not founded as a state institution, gradually the influence of the non-mublic memora of the association lagged behind that of the leading membership of the feich indister of Communications. In fact 1932 a renewed effort was tade to transform the institute into a regular everyweatal department but before it could be decided, the Nasi revolution occurred.

The Mazi Tevolution

When the Hitler forces seized power in January 1933 DV, had a force of 460 personnel. Strangely enough it was decided by the Maxis that the Institute should retain 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 relationship 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 be not out during the Forld Far I. 21

^{13. &}quot;de Deutsche Versuchsanstalt für auftfahrt," in <u>Die Luftwacht,</u>
Heft 11. Nov. 1327, 636-637; A. Pacumker, "25 Jahre DVL," 101.

^{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 safer to entrust trade secrets to the IVI for examination. Desing address at the Annual Secting of the <u>Missenschaftliche</u> <u>Gesellschaft für Luftfahrt</u>, June 1925, in MACA Intell. Lib.

^{20.} Filhelm Hoff, PResearch work of the IV., in Aeronautical Reprints, Vo. 60, Capt. J. Pritchard, ed., (The Royal Aeronautical Society), 1931. 4.

^{21.} A. Baeumker, "25 Jahre [VL," 101-102.



It was only natural that in mobilizing the resources of the state for war, the Easis should pay riose attention to the structure of their aeronautical research institutions. Then Hermann Joring became Reich Minister for Air on 5 May 1933, there immediately began for TWL an anormous expansion of facilities and tasks. Its administrative structure was everhauled. The gap between BVL and the 'untwaffe was narrowed by bringing the new president of TWL's council, Ir. Ing. 'oppenburg, and the new director, Er. Inc. F. Seewald, into close relationship with the two closes of the Technical Section of the Reich Air "Inistry, Taj. Seneral Timmer, and Col. Lanst Udet, as well as State coretary for friction Jeneral "Ilch and the then chief of the Luftwaffe Administrative Office, Lt. Jen. Thort Fesselving. Officially BVL was under a committee of nine members, all named by the Feich Minister for Air. 22

It should be noted, and it was quite in resping with German attitudes toward science, that the first step taken by the Wazis was not to build aircraft, but to expand their research facilities and to adopt a long-range research program. Bimificantly, Coring felt that the research could only be accomplished effectively if all branches led up to a single unified, policy-making head. Hapidly he expended 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 DV 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 norm elaborate than our Wright Field plus all four Newy development work, plus all of the Sureau of Standards devoted to aviation," 23 It had become all this, and a MACA as well; with the added advantage timt it could operate with "apparently unlimited appropriations." Joience now could mlan full-scale wind tunnels, laboratories, research factories, with no regard either for the cost or for the political opposition. Aller Came that I'V had jone further into flutter work than American laboratories, while two years later the research director of MACA, Dr. George W. Lewis, discovered that German factory technique" appears to be the equal of or superior to that of the United States and their costs are less, 24 Dr. Lewis found IVL alone using some 1,400 people in its elaborate installations. Her wind tunnels were under construction at several points. Gottingen now had one negating 15% by 23 feet, while the new DVL atmospheric tunnel was 16.4 x 23.0 feet. The close relations with the other institutes and with industry were maintained even more vigorously, and DVL even operated a school for test pilots in an effort to bridge the gap between theory and practice.

The Lir Hinister could order the enstruction 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, Joring directed the inister for Science and Education

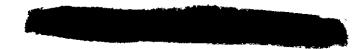
24. "inutes of Special Feeting, Technical Idvisory Committee, United Airoraft Corporation, 7 Jan. 1937.



^{22.} Ibid; "Tie Doutsche Versuchsenstalt für Luftfahrt," (apocial pamphlot printed for Joint Westing of TVL and V.F. 11-12 Not. 1935).

^{23.} E. T. Allen, "Report of German Trip," 3 how. 1935. This is a confidential report submitted to NACA by him upon his return from Germany in 1935.

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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 extablished in the years following the Maxi assumption of power.

Although the new DVL 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 DVL 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. Henschel, for example, worked very closely with Gottingen, as well as with DVL, while the Aerodynamical Institute at Anchen 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 (1935) Junkers maintained over 20 project engineers at Gottingen. 26 Heinkel had installed a single-return tunnel by 1936, Daimler had one, 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 Bodensee, Desserschmitt had W. Lippisch working on tailless planes, and the A.E.G. had made good progress on controllable pitch pro ellers. 27

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 fur Luftfahrtforschung or VLF) created on 28 April 1933, 28 an organization which soon embraced all aeronautical and experimental work in Germany. It consisted of an advisory board, branch committees, and sub-committees devoted to specific problems. Oddly, there were no permanent members; the only permanent elements in VLF were the council, the clerical staff, and the chairmen of the boards and committees. All other scientific and technical personnel were merely invited from time to time to collaborate only on such subjects

26. Dr. Ing. E. Ruhl, "Die Rolle von Forschung and Versuch in der Praxis des Flugzeugbaues," in <u>Henschel Heft</u>, undated, 39-40, in NACA Intell, Lib. 27. John J. Ide, "Report of NACA Technical Assistant in Europe," 23 Oct. 1936;

^{25.} Address of Reichsminister for Air, General Gring, at opening session of the <u>Deutsche Akademie der Luftfahrtforschung</u>, 1' Apr. 1937 in <u>Jahrbuch</u> 1937 der deutschen <u>Luftfahrtforschung</u>, 3-5.

^{27.} Join J. Ide, "Report of NACA Technical Assistant in Europe," 23 Oct. 1936; "Research in Germany," in <u>The Aeroplane</u>, Vol. LXII, No. 1600, 23 Jan. 1942, 94.

^{23.} A. Daeumker, "Die Vereinigung für Luftfahrtforschung," (paper read by Baeumker at Joint Meeting of DVL and VLF, 11 Oct. 1935), in NACA Intell. Lib.



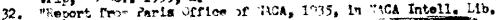
were pertinent to their own respective fields of investigation. Chairmen of the committees were nutstanding specialists chosen from scientific and "practical" circles, selected exclusively for their ability to detect and develop reportly the needs of their branch. As chairmen of the committees foring even preferred men who were not themselves directing research work, believing that they would thereby purrantee a more neutral treatment of the problems before the committees. On the other hand, the scientific personnel of the committees generally were members of the various seronautical research institutes of the country; furthermore, care was taken to assure that representatives of both government and industry were represented at all committee meetings. The the purpose of enabling an exchange of information and experience between industry and science, technical discussions and lectures were held at larger meetings of some 50 rembers (larger, that is, than the small VLI sub-committees where preparation of promains is accomplished.)

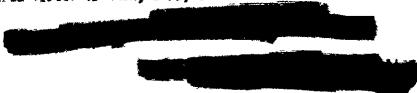
Each sub-cormittee held two such large meetings annually, and each was devoted to be one general subject; it was held at such locations where the lectures could be supplemented by practical demonstrations. Forwally, personnel of the research laboratories would be summoned to those meetings, but it was enstowary to invite capable young university students to attend, as well as interested foreigners. 30

Here then was a central clearing house for the entire deman aeronautical research effort. Once established, V.F was able to direct every
phase of research, for it brought into direct contact with povernment and
military the representatives—and researchers of the universities, the
technical institutes, all private experimental laboratories, all factory
research, and the new enormous VL. Through its committees it could observe
the progress of investigation in every field; it could assign a problem to
that agency be leved to be best equipped to solve it. And if a given problem research slowly, it could throw increased support to rove it shead.
V.F thus was able to initiate research for the entire German aviation
industry as well as for the fuffwaffe.

Another atency established by Goring as a necessary adjunct to research was the Office of aeronautical Intelligence (Antrale for Missenschaftliches Berichtswesen uber Luftfahrtforschung, or MB), created on 23 March 1933. Its function was to serve as a central ajency for the collection of all reports soncernin; aviation, including the results of research and experimental work. 258 became the official denository for all aviation information operating under the management of FVL at idlershof, it classified and duplicated reports for subsequent dissemination to industry and the operators of alreraft. 32

^{30.} Thid: A. Baeunker, "25 Jahre "F", " 103; E. T. Films, "Report of German trip," 3 Nov. 1935, 2.





^{2&}quot;. Ibid. is wight be expected, the Air Ministry was well represented.

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 bilienthal 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 Assolcation for Aeronautical Research (VLF) 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 Acadeny of Air Research (Deutsche Akademie der Luftfahrtforschung), created by Hitler's decree on 24 July 1936 for the express purpose of recognizing the technical and scientific leaders in the field of zeronautics. 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 Wilch, general Inspector of the Luftwaffe. Moreover as patron (honorary) members was the top military hierarchy of the Luftwaffe and its AA division, including Hugo Sperrle, Ernest 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, Ernest Heinkel, and Willy Messerschmitt, with Ludwig Prandtl occupying a special position of honor. 34

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 Villiams. 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 astomished 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, Fright Field, and the Naval Aircraft Factory. 36

34. Introduction to Jahrbuch der Deutschen Akademie der Luftfahrtforschung

26. R. A. Saville-Sheath, "DVL", in Aeronautics, Vol. 4, No. 3, Apr. 1941, 56; Aviation News, 9 Oct. 1944, 26.



^{33. &}quot;Technical Institutions in Germany," in The Aeroplane, Vol. LI, No. 1321, 16 Sep. 1936, 357.

^{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.



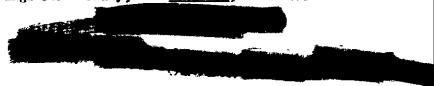
More important was the product of the German aeronautic laboratories. As an indication of the energy devoted to research, the Journal of the German Engineer Society in 1932 carried a list of over 1,300 engineering research projects exclusive of chemistry, covering 26 pages of fine print; many of these are 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 gaspin;—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 DVI, in the numerous institutes, as well as those from the laboratories attached to Dornier, Heinkel, Junkers, and Focke-Tulf. 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 to ps to be tolerated but not accepted by polite science. Prof. Wilhelm Jost of Leipsig 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 wast 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 alreaft, the ME-109 and the FM-190, have ranked among the world's best combat planes almost throughout the war, while the JU-33 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 pursuasion 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 VLP achieved in the field of aviation. The

^{40.} E. T. Allen, "New Wings for Germany," in Aviation, Dec. 1935.



^{37. &}quot;Ingenieurforschung an den technischen Hoschschulen und Bergekademien," in Zeitschrift des Vereines deutscher Ingenieure, Bd. 76, Nr. 42, 15 Oct. 1932, 993-1024.

^{38. &}quot;The Jerman Way of Research," in The Aeroplane, Vol. LIV, No. 1399, 16 Lar. 1938, 329.

^{39.} Explosions-und-Verbrennungsvorgange in Gasen, Dr. sc.nat. Wilhelm Jost, Berlin, 1939. Jost was a professor in the Physical-Chemical Institute of the University of Leipsig. His volume includes 518 pages of text, is jammed with graphs and formulae, 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. Al Morsover 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 other wen 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 reasured; certainly the outcome of the war has upset any opportunity for an objective assessment. But there is evidence that the Maxis 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. 44

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 DVL, was severe in als criticism of what he called the scientific "laity" 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 phrasedit, "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.

^{41.} E. Y. Hartshorne, "The German Universities and the Government," in The Annals of the American Academy of Political and Social Science, Vol. 200, Nov. 1938, 224.

^{42.} Thid. 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 64.4 cer cent, exceeding the loss of any other field.

^{43.} Quoted in Friedrich Seewald, "Forschung als Grundlage des technischen Fortschrittes," in <u>Jahrbuch 1937 Der Deutschen Luftfahrtforschung</u>, 16.

Acronautical hosparch Institutes in Jermany, 1937.

- I. Foutsche Forschungsanstalt für Jegelflug E. V. (FFJ) Larastadt. | Irector: Fr. phil. kalter Jeorgii
- 2. Seutsche Forschungsanstalt für Luftfahrt E. V. (SFL) Braunschweig. Firector: Dr. phil. Blank
- 3. Doutsche Versuchsanstalt für Luftfahrt E. V. (DVL) Berlin-idlershof. Firector: Dr. Ing. Friedrich Gesweld
- 4. Aerodynamische Versuchmanstalt Böttingen D. V. (AVA), in the Taiser Wilhelm Besellschaft zur Förderung der Fissenschaften. Firector: Dr. phil. Fipl. Ing. Albert Bets and Dr. Engelbrecht. Chairman of the Council: Ludwig Prandtl.
- 5. Flugfunk-Forschungsinstitut Oberpfaffenhofen E. V. (FFO)
 Cherpfaffenhofen, Oberbayern.
 Tirector: Frof. Dr. ver. met. .ax :ieckmann.
- 6. Aerodynamieches Institut der Technischem kochschule Aschem. Lirector: Prof. Pr. Ing. Carl Rieselsverger.
- 7. Flugtechnisches Institut, Technische Mochschule Berlin. Lirector: Dr. Ing. Merbert Jagner.
- 3. Institut für Luftfahrtmesstechnik und Flugmeteorologie, Technische Hochschule Braumschweig.
 Firector: Dr. phil. Helmrich Toppe
- 9. Aerodynamisches Institut der Technischen Abchachule Darmstadt. Lirector: Tr. Ing. F. J. Scheubel.
- 10. Institut for Acromechanik und Flugtechnik, Technische Hochschule Hannover. Firector: Fr. Ing. A. Pröll.
- Il. Trahtlostelegraphische und Luftelektrische Versuchsstation, Grafelfig bei Einchen. Treetori Prof. Dr. rer. nat. 'ax Dieckman.
- 12. Fingtechnisches Institut an der Technischen Hoshschule Stuttgart. Firector: Fr. Ing. Room; Budelung.
- il. Porsehungsinstitut für im Lährwesen und Tahrseugsotoren an der Technischen Rochochnie Stuttgart. Pirector: fr. Ing. Numibeld Russ.

Additional Institutions while coffer instruction in Aerona sties.

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Vittaeida, Ingerieurschule	private
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Part E

RESEARCH A D DEVELOPMENT IN RUSSIA AND THE SOVIET UNION, 1914-1939 1

Russian aeronautical science in the prowar years was more a promise than an achievement, for it rested on nothing live 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 arry and the civil service and to present a front to western Europe. Nost 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 Mendelyeev (chemistry), Borodin (aldehydes), Pavley (biology and medicine), Sikorski (aeronauties), Metchnikoff (zeelogist and bactericlogist), 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. What 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.²

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 merenanties, 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 DVL. Yet the Russian government had speak the equivalent of \$12,000,000 on aeronautics from 1908 to 1913.

Russian interest in basic aeronautical research centered around the work of N. E. Joukewski of the "oscow Technische Hochschule. Mere, prier 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 Joukewski, while the work was supervised and executed by A. N. Touppoliev, 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.

2. J. D. Bernal, The Social Function of Science, (London, 1939), 236.

^{1.} Prepared by Capt. K. J. Rohfleisch, AFIHI, April 1945.

^{3. &}quot;Report to Chambre des Deputes," Session de 1933, by Paul Perrin, Report Mo. 2201, (Extract on Organization of Instruction and Research in Soviet Aviation), in NACA Intell. Lib; B. N. Jurieff and N. P. Lessnikoun, "Aerodynamical Investigations," in Transactions of the Central Aero-Hydrodynamical Institute, No. 33, 1928.

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 abler designers to Russia, where the Russians gained an easy access to German methods. Junkers had established a plant at Fill 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 advances 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 geronautical research. This was the Central Aero-Hydrodynamics Institute (ZAGI), founded in 1918 on the initiative of Prof. N. S. Zhukovski 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 dogma 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

5. A. I. Nekrasov, "Design Progress in the U.S.S.R.," in <u>Aircraft Engineering</u>, Jan. 1936, 3.

6. "Report to Chambre des Deputes," Paul Perrin.

^{4. &}quot;Russia's Air Power," in <u>Flight</u>, Vol. III, No. 1727, 29 Jan. 1942, 92-93; General Niessel, "L'Aviation de L'U.S.S.R." in <u>Revue Scientifique</u>, No. 8, 25 Apr. 1936, 236.

^{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 petween Soviet social philosophy and that of the Western democratic states 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 mowers—which are the things that really matter. 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. Parkists 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 rhose goal is immediate and profitable sale upon the open market. Thus it is claimed that free rain 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 dogue, 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 Joylet science and the common welfare of the state.

^{5.} Crowther, <u>Soviet Science</u>, 19; Bernal, <u>Social Function of Science</u>, 223. In the United States witness the relative stature in public esteem of Fr. Charles Kettering as compared with that of E. O. 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 i. W. Toupoliev, one of Russia's foremost aircraft designers. It is assumed that these individuals were removed on prounds 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. 10 Thus the academy became the administrative focal point of all scientific activity in Russia. It is the agency which carcels 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 organised in a division known as the Scientific Research Sector (NIS) of the Peoples! 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 Karpov Institute of Chemistry at Moscow, the Optical Institute of Leningrad, and the Institute of Chemical Physics at Leningrad. 11 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

^{10.} Bernal, Social Function of Science, 226, 444.

^{11.} Crowther, Soviet Science, 24.

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

It sho ld be stressed that the L.J.J.A. 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 menter 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 arricultural stations. The pattern of operations is hierarchical. Industry feeds its problems to the technical institutes; if not soluble at this level, they are passed on up to the Academy for a more fundamental attack.

The Soviets have attempted to implement the Farxist 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 2/10 of 1% of the national income, as against a British contribution to science of 1/10 of 1%.

Even allowing for discrepancies in exchange values, there could be no doubt that Russia was preparing to permit free play for the resourchers within the fracework of her pullosophy. In her schools science was taught from the earliest grades, while in the universities it was "extremely thorough and effective." And anong her people there prevailed a wast popular interest in scientific books. Translations of foreign scientific works often out-sold their native editions in the country of origin. 13

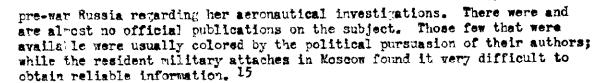
Ahat all this will add up to can not be assessed at present. The first Soviet reneration had not yet been ranted time to contribute to world science before the war engulfed it. But up until the outbreak of the war, J. F. Bernal, the British physicist, found that Soviet science was quite uneven in quality. There were high achievements in some fields, such as animal psychology, plant and animal preeding, agronomy, geology, and certain branches of mathematics. But in others—and simificantly, in the technical sciences, such as chemistry, he concluded that the Soviets still lagged behind. It is highly probable that they will not rest until they move 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 Mussian aeronautical research is to be examined, that is, on the very limited scale which the Soviet government has permitted. For only the most framework information energed from

^{12.} Bernal, Social Function of Science, 44%

^{13. &}lt;u>Toid.</u>, 65, 224, 228.

^{14.} Ibid., 13.



Brain center of the aviation industry was, and presumably still is, the Central Aero-Hydrodynamics Institute of "oscow (ZAGI), which in 1936 had four large wind turnels, plus a number of smaller ones, and comprised four sections revoted, respectively, to engines, materials, hydraulics, and aerodynamics. Administratively, ZAGI was under the Commissariat for the aviation Industry, which co bined 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 (VIAK), which are in charge of testing and accepting new equipment. ZIAM has a factory "or 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 Waval Air Arm operated a research institute; the Research Institute of the Civil Air Fleet comprised four independent establishments at floscow, plus one at Kiev, and another at Kharkov; and the Red Air Force maintained a special institute devoted primarily to navigation problems. 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 Connissariat fur 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 AAGI'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 emodded 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 Villiams, 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, sen the reserved their judgment."

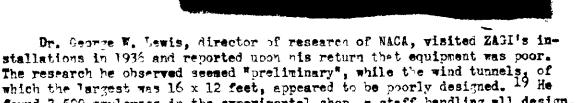
^{18.} Interavia, No. 770-771, 27 June 1941, 2.



^{15. &}quot;Notes on the Air Forces of the U.S.S.R.," by Air Staff, (M.I.B.),
1 Jan. 1940, in A-2 Lib; H.J.A. Wilson, "USSR Air Force," in <u>Aeronautics</u>,
Vol. 4, No. 5, June 1941, 42.

^{16.} General Niessel, "L'Aviation de L'U.R.S.3.," 241; "Notes on the Air Forces of the U.S.S.R.," by Air Staff, (M.I.D.), 1 Jan 1940.

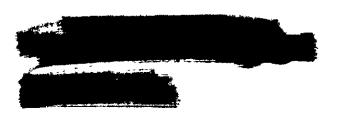
^{17.} Interavia, No. 500, 13 Dec. 1937; "Description of Central Aerodynamic Research Institute TSAGI in Moscow USSR," U.S. Military Mission, Moscow, Report No. 2610, 9 Sep. 1944.



which the Targest was 16 x 12 feet, appeared to be poorly designed. 19 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. '. Phaylamov, stated that lack o' 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 Jerman to American designs. Russian engineers inspected many foreign plants and concluded license arrangements with Hispano-Suiza, Grome et Rhone, and Curtiss (Cyclones). For aircraft they went to Martin, louglas, 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 cony of the Martin 139 twin engine borber. On their reliance pon 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 Mar, 21 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.

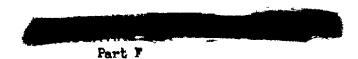
^{21.} H.J.A. Filson, *bSSR Air Force, in Aeropautics, Vol. 4, No. 5, June 1941, 42.



^{19.} Minutes of Special Nestin:, Technical Advisory Committee, United Air-craft Corporation, 7 Jan. 1937, NACA Intell, Lib.

^{20.} Interavia, No. 770-771, 27 June, 1941





RESEARCH AND DEVELOPMENT IN ITALY, 1914-1939 1

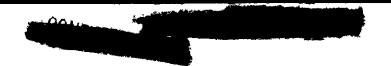
Aeronautical research and development in Italy since World War I has been a reflection of the political and economic condition of the country. An account of research and development which ignored that fact would be practically valueless; the factual data without its context would be highly misleading. The decade that followed the Armistice of 1919 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 perforce gave 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 prowing 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 so pitiful a state of numerical weakness that, but for the sadness of it, it might be termed a reductio ad absurdum. . ." Until 1922, Gen. A. Guidoni 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 co-operate 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, AFIHI, March 1945

Guidoni, "The Re-Organization of Italian Aeronautics, 1923-1926." in Jane's All the World's Aircraft, 1926.



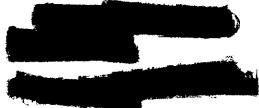
Civilian Aviation, since Italy was too poor to undertake the development of both civilian and military aeronautics, but it was not until the Fascist government was strongly enough established to tackle the problem that Italian aeronautics was given a new lease on life. This sourced in 1923.

In January the new cabinet instituted a reorganization of the whole field. Mussolini headed the new ligh Commission of Aeronautics, the chief subdivisions of which dealt respectively with civilian and military aeronautics. Before the end of the year telltalian Air Force was adde independent of the Army and Navy. Incentives were immediately viven to the development of new aircraft and envires. Five million line was set aside for an aero-engine competition with prizes up to one million line to o to companies competing in the French aircraft engine competition. A prize of one million line was offered for a trans-Atlantic flight and a prize of 100,000 line for a Rome-Tripoli flight. Many <u>bruppi Fascisti Aviatori</u> were created by the Fascist Party in the principal towns to back up the governments effort to restore Italian aeronautics. 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 Furbara, 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. Nowever, until the creation of the Guidonia 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.

is 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, Mavy, and for Air."4 The year sag miso marked by the transfer of meronautical 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 18 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 lavy.

^{4.} Gen. Guidoni's historical article, in Jane's All the World's Aircraft, 1926.



^{3.} Jame's All the Forld's Aircraft for 1923, 1924, 1926.

By 1925 the geromautical 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 stren themed meronautical industry which could bid successfully in foreign markets for aeronautical equipment. National wrestige 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 aggrandisement as a consequence of her meticipation in World "ar I wan a national humiliation. Restrictions upon her exports of her products and her survius conclution as well as upon her free access to important raw meterials, were disadvantages keenly felt by the Italian people. The inscist government, in its effort to build un international prestige, sought to make the nation willtarily strong, economically selfsufficient, and to miss no orrortunity for the development of a profitable foreign trade. The reordanization of the air are reflected all these sime. The ranid equipping of some 9D air squadrins markedly enhanced Italy's relative miditary strength with respect to other sations. The development of civil acromatios and the extension of Italian operated sirlines increased the nation's prestigs while at the same time it provided a certain economic support for the expansion of the mireraft industry which was of even greater william military and advenced state of Italian military and civil aeronautics, it was expected, would create a demand for Italian airoralt in foreign countries, thus providing further economic support for Italy's essential niroraft industry, while at the same time the export of Italian riroraft would contribute to the growth of prestige and provide foreign exchange which could be used to provide essential raw materials for the arronautical and other industries as well. The widespread consciousness of the importance of prestice moons the Italians was reflected in the formal establishment of properanda agencies in its major civil and silitary organizations.

In the filfillment of this program, aircraft manufacturers, encouraged and mided by the povernment, developed aircraft for international competitions and the capturing of various kinds of international records—speed, altitude, and enurance. In Italy, as elsewhere, these exploits contributed to the development of moralar pride in the achievements of Italian aeronautics, and encourage ently support for the expensive povernment development of military and givil aeronautics.

^{5.} In 1925 Comm. Francesco de lindo flew from one to depen and returned by man of elbourne, hustralia--a distance of 35,000 miles; in 1926 the amund-nen-filsworth-fooils expedition employed a semi-rigid Italian-built airship, the "Morge", in a flight over the North fole from finus May, Spitzbergen to Tellar, Masia--a distance of 2,700 elles; in 1927 Comm. Francesco de Pinedo's A doubleent flight--Africa, but h American, North America, Nem-foundland, 'somes, contugal the operationed in the copular mind by the flights of Indbergh, Chamberlin, and by d during the same year; in 1927 Maj. "The armindicatablished coeld sea plane record of 2 77. The P.P.H.; in 1927 Capt. Turn Tererin and Maj. Carlo P. Pelprete made a non stop flight for the forest to Tracil--a listance of 4,456 miles.

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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 axist. 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. O 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 out 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 wisw to maintaining and enlarging the general productive capacity. 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.

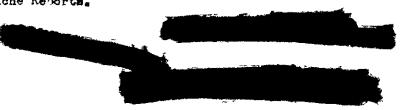
The government fostered the development of air lines by direct subsidication through out-right grants, maintenance subsidies which were standardized at a sum equivalent to one-half of the cost of air miles flown. Indirect subsidization of both civil and military aviation was given through the assumption 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, premises for studies and inventions, expenses for military aeronautical propaganda, statistical work, and confidential expenses. The Air Ministry paid funds to civilian pilet training centers for the complete training of a flier, for partial training, and for refresher training of reserve fliers.

7. Ibid., and Military Attache Reports.

8. <u>Ibid</u>.

9. Ibid.

10. Ibid.



^{6.} Report Covering Aviation Laws, Regulations, and Policies in England, France, Italy, Japan, Russia-1934. AAF Library & 12.6-2.

plowever, the importance of basic scientific research and best blearly recognized by the povernment which, from the peginning, was confronted by the country's lack of rewesterials essential to her manufactures. A solution to this difficulty was sought thro in the laboratory, and during the first decode of Pascism a broad program of research was vigorously advanced by the government with important consequences in agriculture and industry. It 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 1030-1936.

In 1930 the Air inlatry was authorized to spend 30 million line over a period of four years for "the necessary works in connection with the organimplied of a pritor of studies, tests, and aeronautical construction at Fontecelia was the experimental field of the R. commentics outside Rose, but in 1930 it was rather primitive and possessed little equipment for experimental work. The expension of the experimental center at Montecello, remared the G ideals Experimental Center, dominated the history or Italian perchautical research and development furing the next decade.

The late of the establishment of this experimental center probably has some significance. During the first period of the expansion of Italian meronactics under Pascist ruspices, Italy was not nearly so seriously handicapped in the matter of rew materials as she was later. In the late 1920's there was a noticeable trend exong newer types of aircraft toward the more extensive use of metal in construction. Norbans 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 its to the fact that the construction of her air force had taken place during a period of relative world peace when armment corpotition among the mations was being de-emphasized. 4t any rate, the % Acronautica had achieved impressive numerical strength. The problem which lay shead was to ee; the notion abreast or shead of the rest of the world in new developments. As the Pascist government entered its second decade, it was apparent that Italy's position as an important mir power would become increasingly difficalt to maintain as murent industrial nations entered the competition and as norm modern, gireraft increasingly employed materials which Italy could not provide.

The construction of the Guidonia Experimental Center at Montecelio extended over a period of approximately six years. The work actually be an

It. Meticnal Resources Flanning card, Cosearch-A lational Resources

II. Industrial Research (1941), pp. 206-209.
12. G-2 Report : 12268, 9 Tecember 1930, Name, Italy, in files of former OC'C file "3640 Italy-Guidonia", Information livision (now in ATIII).

^{13.} The progress of the Fildonia experimental center may be followed in Military Stache reports, in the reports of the PACA Technical Assistant in Europe, and in items mullished in Inter-Avia, a leneva news letter devoted to neronalties which was sublished three times a week, as well an in a series of articles appearing in technical and aeronautical journals.

in 1929 when stops were taken to construct a wind-tunnel at Montecello, 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 Hillitary Attache reported that "The R. Aeronautions Experimental Center is the Italian equivalent of the N.A.C.A Isboratories and Wright Field combined. Theoretical and practical experiments as well as flight tests of new land planes are carried on at this station."14 He estimated that some 50 million live had been expended on construction and installations. Marlier in the year MACA representative reported: "The equipment here comprises a towing basin 1,450 feet long with possible extension to 2,600 feet; identical single-return tunnels for routine tests with throats 6.6 feet in disseter, and speeds of 157 miles per hours 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: "s 13-stage, 2,900 horsepower, 3-atmosphere supersonis tunnel has been sompleted at Guidonia, in which a speed of more than twice that of sound has been reached, together with temporature of -980 C. and pressure equivalent to that at 75,000 feet." 15

This last fact is of special significance, for it was in the study of supersonic special and stratospheric flight that Italian research gained the advantages of initiative. In an introduction to a published interview with Sig. Crosco in August 1934, the editors of Inter Avia noted: "Preceding all other countries in this respect, Italy has areated a technical department for stratospherical research, known as the Riparto d'Alta Quota and having the cooperation of the most eminent scientists and authorities of Italy," 16 At the same time a high-speed school maintained by the government at lake Carda enabled Italy to retain the world speed record for several years. 17

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 magnificant new air city of Suidonia," where the government has assembled a corps of scientists, each qualified in some special form of aeronautical research. Is 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 leads. In mountainous country

^{15.} G-2 Report L. 15584, 27 October 1936, Italy. See also reports #12268 and #11499.

^{15.} Notes on European Aeronautical Development in 1935, by John Jay ide, Technical Assistant in Europe, National Advisory Committee for Aeronautics, 14 January 1936, the same "in 1935," 17 December 1936, in AAF Library D 52 = " - 1935 and D 52.1 = 1 = 1936.

^{16.} Inter Avia, No. 142, 20 August 1934, p. 1.

^{17.} Aircraft Year Book, 1936.

^{18.} Told.; for extension of trend see Notes on European Aeronautical Development in 1937, by J. J. Ide, N.L.C.A., 7 January 1938, AMF Library 52.1 - 1 - 1937.

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the low ceilings of the planes were a serious handicape. If this it is true that the as permutica via not send its cest aircraft to abyssinis it is also a fast that the air lords built up during the 1920's had become obsolete and that equipment had not been replaced.

In 1934 the suce encoursed that 1,200,000,000 live would be spent during the course of the last five years for renewing old and obsciete aircraft. Late in the year the military Attacks in hose observed: "The policy of building principalty experimental prototypes, which was followed up to the present, will terminate in the car future. The period of replacement of old and obsolute arroraft in the LAD squadrons existing in Italy will begin soon. 20 He further reported that about 30 squadrons of the Mr Agronautica were equipped with obsolute or obsoluncent types. No planus were equipped with superchargers—as interesting fact considering the theoretical and experimental interest in high altitude flight, less than ten percent of the service times lad actual propellers, and no planes in service were equipped with variable pitch propellers. Li Furthermore, Italy had continued to manufacture planes of wood and fabric construction despite the almost universal adoption of all-metal construction. To american Military attacks 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 craftemen for wood-fabric work and the possibilities of rapid expansion, the availability of materials in Italy which obvicted the necessity of making purchases abroad as well as the danger of being cut off from essential materials in the event of war. 22 Electric welding of duralumin had not yet been attempted b. Italian aircraft manufacturers. and with a single exception all work with stainless steel and Budd process of walding had been discontinued. This too w.s attributed to the necessity of importing steel, the cost, and the difficulty of obtaining trained workers. 23 The same considerations resulted in the determination to use easter oil for the lubrication of both aviation and automobile engines. 24 And the same necessities determined the persistent efforts of Italian scientists to perfect the "gasogene" engine which burned a fuel manufactured from an indirenous shrub.

Impressive as was the set-up at Guidonia, the sums of money spent on its development, and the coordination of the research facilities are personnel of industry, the universities, and the military service, 25 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.} G-2 Report L. 14109, 1 November 1934.

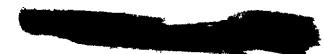
^{21. &}lt;u>Ibid</u>.

^{22. 0-2} Report L. 13898, 29 May 1934, Rome, Italy.

^{23.} Ibid.

^{24.} G-2 Report L. 14564, 11 July 1935, Rome, Italy.

^{25.} It should be noted that this bleakdown is highly superficial, for the same individual often occupied a prominent place in two or all of these categories. G. A. Crocco, a prominent member of the R. Accad. d'Italia, was a Lieutenant General in the Hoyal Corps of Engineers and Professor of General permantics at the University of Rocs.



Before the launching of the Abyasinian campaign, Roars and Laval had allowed ussoling to think that uncland and France sould stand uside and regard the conquest as compensation for Italy's failure to receive important territorial concessions at the close of ford far I. The violent popular reaction to the flogrant ent of greatent of pression, particularly in England, took the Tuce by surprise. Italian reaction toward the Abyasinian war was at the outset either profite or in the line. To seek this shouldness which pitch of chausinian for the provincent, the Italians were nor edup to a high pitch of chausinian by a vigorous company, and the rail engan lon of Italy's allitary force was undertained. Italian air power was built up as a counter threat to infinite sea power in the editorranean. This point is that Italy was forced to expand her air power pefore per program of research and development had over remisected.

great air Jorce has been built up by Italy in a remarkably short time and at a come in lively moderate must do to the milespread and of welled-steel tubes for the fiseless sembers and wood wings. Special emphasis has been placed on the production of bombin simplement and of extreme tension between to the Pritish Mediterranean Flect at the pariod of extreme tension between the primary appears records with especially built aircraft, Italy exected an illustration of exceptional source the police opinion was such stirred by the holocaust of records which Italy and lergely now with its in the part of reach of existing Trench airplanea in respective and microscopinion, of the training species of the remaining opinion. And in the part of tally it seems to have been largely a nucleus of the trias, but on the part of tally it seems to have been largely a nucleus all bit Tt.

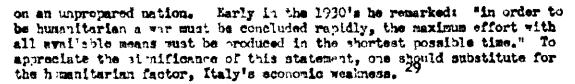
The rapid march of events which events may be brilled the rations of throps in forth aw II placed a strain on the ten resources—managers, compared, and fine relative which he a fire an interfer, and once the france Rebellion to Justice for the fire sid, which are not constraint to see the spring of 1030. This arrows was accumpated by the onestmentian of firmidable aircledge and submarine bears on important to 110 Telegraphs by the Italians. The Albertan concrete of and 130, while not expected to costly enterprise, was an additional tax on limited rear more.

Italy's economic weakness forced "ussoling to lay a game of bluff in confirmation the more someth) Burn mean states. His tactic from the stark was to take advantage of the stark of unpresentations of the non-baselist nations, to comprehent Italy's state of suppresentations, and it emphasize the importance of the initial income that on it is initial income.

^{17.} Iohi.
Lie or a month, ortal discussion of the or about use . the other, inscist lists, "irrespension olitical cicaco derica," 1929, Chap. fk, p. 121-277.



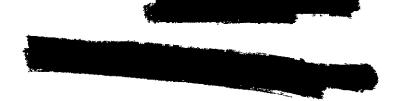
^{2.} Motes on hur open ser nautical perologiant in 1937, by J. J. Lie, E.A.C.A. 7 January 103, 1 1 1 library 52.1 - 1 - 1937.



'n "urope approached World War II, the weakness of Italy's position became more and more clear. In 1939 it was noted: "As in other totalitarian states the matibial economy of Italy is directed toward self-sufficiency and preparedness. Italy is a lacking it material resources and her populati m is so prediminantly a micultural that her aims toward self-sufficiency have been realized only in relatively small degree." 30 No amount of "doubletalk" was able to obscure these facts. In March 1940, General Pricolo, Undersecretary of State for Air, presented the Air Budget for the following fiscal year. In doing so be discussed the production rates of various countries, during the course of which it became clear that Italy's expanded production espacity would be inferior to that of other countries.

To overcome this factor, it was made apparent that the covernment 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 "fustest with the mostest." Pricolo 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 standardisation of materiel, that is, of reducing to a minimum the number of standard planes, engines, arms, equipment." Later on he added: "The potentiality of geronautical construction naturally depends up in the availability of raw materials. Without going into details I can affirm that the Air Ministry and industry obey the order to use mational raw materials, for we are convinced that though this is sometimes more costly, it is nevertheless to the interest of the metion," 32 The Military Attache noted: "As far as facilities are concerned the industry is capable of considerable expansion. The programment of essential materials, tools, skilled personnel, however, rather than the question of facilities, will govern the potential output of industry." 33

Meediess to say, the performance of the nore 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 Kilner Board, in comparing characteristics of foreign aircraft with American military planes noted the superior speed of the Piaggio P-10g over other comparable heavy bombardment aircraft like the Junierland Flying Boat and the



^{29. 3-2} Report.

^{30.} Metional Resources Planning Board, Research - A Metional Resources II. Industrial Research (1941), pp. 207-208.

^{31.} G-2 Report No. 17,431, 18 March 1940.

^{32. &}lt;u>Ibid</u>. 33. <u>Ibid</u>.



Junkers Ju 39. Very significant, however, was the fact that whereas the latter two craft were in production, the threat of the Italian plane was measured to "12 aircraft on order," 34

First the years preceding Sorld bar II, the junior Axis partner found himself in the ridiculous position of a small bully boasting of his alreaght and threatening bligger ways who opposed him with reprisals by his big brother. However, since the combined strength of the two Axis brothers, or markture, was formitable, the oracle set sice considerable success.

The test of mar revealed the weakness of Italian aeronauties. This in turn reflected the inability of Italian research to overcome the disciplinates resulting for a critical shorts to insterials. The picture is reflected in an operations analysis report on the Italian Aircraft Industry to a in input 1943. 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 heros 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 beens (s) low production, and lack of reserves; (b) failure to develop and out into mass production has models comparable in performance to latest Allied models; and (c) poor training.

It was noted that "prior to her entry into the precent war, Italy relied heavily upon imports of many vital naterials, parts, and machinery to sustain aircraft production. The continued inflow of these items since '900 has depended largely upon servan choice in the matter." It is apparent that the Germans initially considered using Italian production facilities to build upother research of both axis air forces by exchanging technical information, supplying necessary raw materials and machinery, sending forman forces of apprecialists into Italian plants, introducing German models, and in general coordinating the industrial production of Italy and German. If Someone, due to financial difficulties Italy has been unable to put her aircraft industry underground. The industrial populations of Piedmont and Conbardy had given evidence of naving tired of Passism and their resentment of German overlordship was acute. It was eventually decided to transport Italian later to German vertex.

Germans. 39. 3-2 Report #17,114, 30 June 1939.

^{74.} It at report of Air corps Doard (Allner Board) on Revision to the 5-Year Experimental Program, 23 June 1939, A. J. Lyon Project Record Record, 8 5 5.

^{35.} Taport to Committee of Operations Analysis by Subcommittee on Italian Aircraft Industry, 26 April 1943, in AAS Bulk Files 334 Committee - Italy.

^{36. &}lt;u>Ibid.</u> 37. <u>Ibid.</u>

^{32.} Ibid. See also 3-2 keport 17,114, 30 June 1937, and Collaborations Scientifico-Tecnics Italo-Germanica. Relations sulls Missions in kommunic, hapast 1942, (in A-2 kibrary, Italy 9545 Encl. File 17 November 1944, D 93055), which, despite its tactful wording is a confession that at this date the fermans were primarily interested in extracting information upon the serodynamics of wings at supersonic velocities and data upon the behavior of bombs in water, fields in which the technicians of Guidonia had obtained more experience and better results than the

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 u of a National Research Council, 40 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 direraft 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 meapon 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 Rene Lorin in 1913. The theoretical and mathematical work had been carried on by G. S. Steckin down to 1924. The Italian engineer 3. Campini, creater of the CC-1 and CC-2 recorded the first fruits of work done in 1929 in an article published in the Rivista aeronautica in 1930. Cen. 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 1932.43

In an interview published in <u>Inter-Avia</u> 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-airscrew 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 atmospherical resistance beyond this mark; and this study of ulta-sonic velocities has only been approached, as yet, by certain calculations of artillery ..."

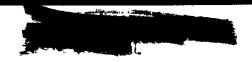
^{40.} Reorganized for more effective functioning in 1928. See Research - A National Resource: II. Industrial Research, NRPB, (1941), for a brief general statement.

^{41.} Sulla Teoria Analitica del Moto-Propulsore Campini in "Aerotecnica", Vol. KVIII, No. 1, January 1938, pp. 18-63.

^{42. &}quot;Caratteristiche e possibilita 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. 45

Campini, working as an Aeronautical Engineer at the Caproni plant, perfected his first model in 1939. The machine was inspected by General Pricolo, Undersecretary of State for Air, in January 1940 40 and the first flight was made with the new plane, the Caproni-Campini-1, on 27 August 1940. 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 propeller, made a test flight from Milan to Rome, piloted by Col. Mario de Bernardi, the Italian Schneider Trophy pilot. On the occasion of this second flight, the pilot, Col. 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 lesign, of which the Caproni-Campini aeroplane was on example.

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. Amusingly 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 "ould Add Greatly to Planes' Speed." This dealt with the announcement by the Daniel Guggenheim School of Aeronautics of New York University, that E. B. Tyers 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. Myers, they had encountered difficulty in obtaining a metal sufficiently resistant to the intense heat engandered to permit of continuous operation for more than a brief interval. Italian experiment seems to have received continuous encouragement as a result of the fact that Sig. Crocco, a Lt. General

^{45.} See N.A.C.A. Technical Note, n. 442, Vol. 1933.

^{46.} Inter Avia, Nos. 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.

^{47.} Inter Avia, No. 733, 28 October 1940.

^{45.} Willy Ley, "Experiments In Jet Propulsion," in Western Flying, December 19/3, op. 43-49, 100.

^{49. &}quot;Jet Propulsion In Italy" in <u>The Aeroplane</u>, London, Vol. LXI, No. 1596, 26 December 1941, p. 697. AAF Library.

^{50.} New York Times, 29 Dec. 1940, X, 5:4, "Air Gurrents" by Frederick Graham, and New York Times, 11 Dec. 1940, articlepited.

^{51.} Ibid.

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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 Pair, 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.





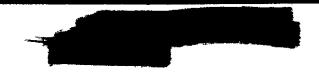
Comparative Statistics on Italy's Serosautical Budgets

The statistics appended cover (1) the Italian aeronautical budget, prospective and actual, expressed in both lire and Pollars, from 1923 in 1941, and (2) subsidies to meronautics 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 outlants of comparative subsidization, one would have to take account of living standards in the various nations concerned from year to year and the actual purchabing nower 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 Ispor that may be purchased by official currency within Japan. Fifter 1933, the published figures on expenditures for the support of germantics by subsidiration or other means, were frankly deceptive. Consequently, the total budget for aeronauties in Italy is considered a more useful index of the situation than any set of figures that could be obtained representing samsidization.



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I.A. 115 A. "(A" TIC'L RELOET, 1923-1941

I mar	"ar Prospective sudget		Actual Expenditures	
	Lire	Collers	'ire	Dollar#
1923	~ ~ ~	-	95,000,100	1,365,309
1/24	100 Minute		257,000,000	11,173,913
1925	pis terretti		450,000,000	17,935,452
1^26	/49,000,000	17,215,636	553,000,000	77, 732, 752
1 327	720,153,000	31,537,443	774,153,000	37,277,168
1 028	71 , 530,000	27,793,375	681,330,000	35,343,054
1727	717, 30,000	37,687,435	757,330,000	70,676,963
1000	735 640,000	37,535,359	775,779,000	40,622,262
1/31	747.014.00	31,971,513	323,077,977	43,243,325
1732	775,663,302	39, 833, 396	300,072,932	41,092,601
7 7 7 7	779,117,410	49,975,459	777,999,374	51,136,416
1724	724,101,100	61,942,524	750,631,770	64,211,460
1935	1,347,651,600		2,959,349,477	244,170,700
1775	2,069,372,700	75,55(,405	3,617,972,700	255,C21,9CC
ริกรัก	1,330,693,600		4,367,698,600	251,017,100
1.738	1,416,964,000	74,577,052	,367,596,000	230,252,400
1,733	1,363,000,000	71,747,100	673,402,000	193,744,700
1740	2,267,060,000		(663,060,000	337,574,301
1741	7,367,573,600	363,374,610	for shoot see	AND A CONTRACTOR
ա երբեր	TELUTE TELEVIO	The result of the contract of		

From G-2 Tayort 17,752, 9 Tuly 1940, Hiltary Stacks, Some, Italy.



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Indirect Subsidies to the Avistin Industry (for military eviation), 1922-1933

Year	angland	Trance	Italy	Japan
1922	91,407,309,	55,734,842.	3,243,239.	1 ,635,260.
1923	74,240,390	101,317,209.	17,374,500	21,130,000.
1924	10,452,508.92	95,227,337.	57,715,000	17,720,000.
1925	67,963,768,76		75,594,50	
192€	72,372,171,64			
1927	70,474,212.08			
1928	77,047,387,92		129,832,700.	
1929	73, 207, 252, 36	43,726,283.	127,342,30C.	
1930	33,732,366.	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
1931	34,321,000	74,911,100.	137,290,260.	30,610,490.
1932	14,316,140.	56,549,110.	133,523,127.33	23,525,306,68
1933	32,065,220.	79.347.227.		41,772,220,54



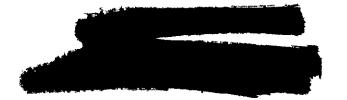
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Expenditures for Civil Aviation, 1924-1932

Year	<u> Ancie od</u>	France	Italy	Japan
1924 1925	1,031,179 9%,341		1,930,500	
1926	1,079,555		-3,0,0,0,0	191,290
1927	394,755	17,206,635	1,463,570	
1924	593,331	19,503,050	6,745,000	
1929	235,165	22,019,327	7,657,700	
1030	1#3,657		670,973	2,001,382
1931	676,727	3,M3,000	147,130	2,092,100
1932	701,609	912,727	152,433	194,025



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irect 3 saides to Air Lines, 100-1033

Year	<u> હારોક્સ</u>	<u>irmee</u>	Italy	Jaman
1 326	3714443	11,415,000	4,227,130	
1)27	1 ₉ ∪32 ₉ ∠32	14,943,500	(*(ô,*50v	
1925	1,130,116	21 350 cn0	¢ * 1 ሗሗ ឺ ሆኒኒ	
1929	1,750,491	6]104].000	- "	24 , 5.0
1930	1,000,000	7,006,090	0,21 1,340	2,063,109
1931	2,527,200		14,155,000	
1//32	2 6777 Ju	5,110,10 1 , 27,158	731,70	2 , 403,050
1933	~~	y way y	, 3- , ,	ง รู้รู้รู้รู้รู้กล้า



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Miscellaneous Aids to Aviation, 1929-1933

(Flying Cl.bs, Private Touring Aviation, Training Givilian Pilots, etc.)

Year	England	France	<u>Italy</u>	<u>Jepan</u>
1923				132,182.
1929				Ann
1930				174,332.
1931	33,091.42	150,000		
1932				•
1933				43,220.13



Fart G

THE ARCHAUT LIVELOPS STATE IN FRANCE, 1914-1940

since the time of Pescartes, scientific investigation has had a great attraction for the Trench mind. In the days of the morerchy and the Manoleonic ambine, the state subsidized and controlled most scientific research, but during the minoteenth 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 realthy patrons. The official indifference, even hostility, which handle-capped the work of scientists like finiteur and the Curies was not unusual during the Third Republic, although since 1900 most governments have tried to do better by Trench science.

As elsewhere, to 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 Sorbonne, (3) the Ecole Polytechnique, and (4) the Ecole Normale Superiours. Is in the land, there has been a tendency for these great institutions to deal more with theory than with the practical application of new Meas, and for some time the French government made little affort to bridge the Jap 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 "closed shops", and to regard with some initial distruct, the ideas of outsiders.

Nowever, after the First Forld War, the poverment has established many new organizations to further scientific research, although it has not always shown a disposition to supply then very generously with funds. In 1922 was founded the Wational Office of Scientific and Industrial Research and Inventions, (Office National des Secherches Scientifiques et Industrielles et des Inventions) to foster research needed by the public services and to coordinate public and private investigation. In 1724 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 1725 as much as 3,000,000 france 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 france for scientific purposes, the Chamber only woted 5,000,000.

^{1.} Prepared by Dr. John T. Lansey, WIHI, Moril 1945.

^{2.} Hearings on 32721, III, 613; Exhibit 42, by Pierre Cot.

^{3.} Ibid. 4. Oregory 3. A., and remlin T., "The Organization of Scientific Research in France", The Scientific Torker, IX, No. 2

When the Higher Research Council (Conseil Superieur 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 'inistry came into power the next year, an under-Secretary of State for Scientific Research was created. The ever-growing threat of war apparently bestirred 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 1933 budget this sum was increased to 12,000,000 francs.

In 1936 the Central Service for Scientific Research (Service Central de is Recherche Scientifique) came into being, and two years later the National Center of Practical Research (Centre National de la Recherche Scientifique Appliquee) was established. Both organizations were coordinated by a committee in the Ministry of Education. 7 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 fine need 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 fusciage, landing wheels, allerons 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. &}lt;u>Ibid</u>.
3. <u>Ibid</u>.

^{9.} Hearings on S2721, III, 613, exhibit by Pierre Cot.

was mainly a wind tunnel and consequently the field of experimentation was somewhat limited. About the same time that the Eiffel Laboratory was created, denri Deutsch de la Meurth founded the Aeronautical Institute at St. Cyrwith s grant of \$100,000 and a prosise of \$3,000 per year for maintenance during his lifetime. The Institute was placed under the technical direction of Frof. "surain, a distinguished accentist of the University of Paris. A large body of eminent scientists acted in an advisory capacity. The scope of the work of the St. Dyr Institute was virtually carestricted. Mention should also be made of the balloon laboratory at Chalais-Weudon which had functioned since 1903. However, this institution did not undertake experiments with heavier-than-aircraft until sometime later.

In 1909, the Inistry of ar greated a men'l military aviation establishment and attached it to the artillery. At the 1910 maneuvres the use of planes in reconnaissance and in fire control created scrething of a sensation, and henceforth their use by French military organizations was assured. By the outbreak of the war, France had spent wore 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-Feudon which was transformed into a laboratory for aeronautics and also served as a genter for aviation caterial.

The var 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 "inder-Secretariat for Air in the War Limistry which had been set up in 1717 was abolished in the year following the war, and from 1720 to 1926, the air force was split up among the Finistries of War, Marine, and Colonies; these fragments were coordinated by an Under-Secretary for Aeronautics and Air Transport established in the Aerial Navigation Section of the Ministry of Public Works. Scientific and technical organizations were placed in a number of Pivisions (Services). The Division of Aeronautics (Service Technique de l'Aeronautique) contained sections on hydro-navigation, ballooning, notors, 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 Studes) established construction progress involving new equipment and inventions, while the Fivisions of Tests (Service des passes) made actual test flights with prototypes.

In spite of these elaborate organisations, 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 need of a better technical direction, and the lack of scientific advances in the industry itself. Writing in 1924, Captain Sene Fonck, a former war ace, stated that

^{10.} Zahm, F. F., Report on European Aeronautical Laboratories 1914, Smithsemian Misc. Col. vol. 62 No. 3

^{11.} Ibid.

^{12.} Annuaire de l'Aeronautique, 1928

...an effective technical direction, and a unified metalleurgical development are the two fundmental needs which both the military and commercial aviation have in common. ... We would be much further ahead if there were more method in our work, if we had comprehended the fundamental relationships between the various branches of seronautics.

de concluded by calling for ambilization of scientists, specialists, inventors, and skilled workeen to eid the eircraft industry.

Some years later, Fierra Ptienne, a writer of some recommon 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 bilometras per hour when there were actually in service british planes that could surpass this speed by 40 kilometres." 14

In 1,26, the Suder-Secretariat was abolished and its powers transferred to a directorate of Aeronautics and Air Transport (Pirection Senerals de l'Aeronautique et des Transports Aerien) attached to the Finistry of Commerce and Industry. The Technical Mission was joined with a production organization known as the Division of Sanufactures (Service des Fabrications) and was remanded the Technical and Industrial Division (Service Technique et Industrial). Thus to questions of research and prototypes were now joined problems of control of manufacture and raw materials.

The Tirectorate came to an end in 1927 when an Air Ministry was established, the following year the Technical and Industrial Division was recorganized and remained the Technical Directorate (Direction Generale Technique). Its purpose, in the words of the directive was to "direct... the researchers leading to the improvement and development of aeronautical equipment."

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

Through a reorganisation in 1931, the Technical Directorate became the Technical and Industrial Division and Air Wavigation Service (Service Technique at Industrial of Service de la Mavigation Aericane) and was divided into divisions controlling research, technical development, manufactures, and mir bases. The first two were entrusted with scientific studies. The

16. Annueire de l'Aer meutique, 1929

17. <u>Luie</u>.

^{13.} Pone't, Rene, Liaviation et la Securite Française, Paire 1924, p. 224. 14. Étienne, Pierre, la Crise Perpetuelle de Notre Aviation Eilitaire.

^{1734.} 15. Nopout, 3. A., La Ministere de l'Air, Paris, 1929, p. 156

Division of Research was divided up into sections concerned with merodynamics, raw materials, and machines while the Technical Division's sections 18 dealt with places, hydroplanes, motors, equipment, armaments, and ballooms. At the same time, the Chamber of eputies provided for an expansion of the laboratory at Chalais-Houdon by a grant of \$1,040,000; a full scale wind tunnel was to be constructed, and an engine testing station set up. This sur bar in addition to the a propriation of 2,537,000 which was all ocated, to research, technical development, and pro-types in the 1932 air budget.

The overthrow of the Weimer epublic and the gabrose but well known rearmement of lermany produced a temporary expansion of credits for the French Air inistry. The 1933 but at amounted to approximately :33,000,000 of which about \$5,735,000 went to aeronautical research and development. However, as time ment on, the Chamber became less nervous about Mitler, and more concerned with saving money and holding down taxes. The air approprintions were not greatly increased until 1936, while the sums available for research were out in 1904, 1935, and only partially restored during 1936.

In 1935 Mitler announced the official rearmement of the Reich, and the following year the Spanish Sivil Far broke out with Berman, and Italy openly intervening. These unhappy events are reflected by increases 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, us it had been in the twenties, to the planes, tanks, and guns possessed by the potential enemies of France. As a regult, efforts were made to bring French science into closer contact with the needs of the Army, Nevy and Air Porce, 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 for Scientific (1936), the National Center of Practical Pescarch (1938), and the Institute of Scientific Researc', for "ati-na! Defense (1939).

Although these organizations dealt in a general way with aer mautical problems, it was felt that something more specific was needed, and consequently the Trench association for the Lavelopeent of Abrona utical Tesearch (Cro perent Trancais pour le Developpement des Techerches Aeronautiques) was created early in 1932, and began to function in July of that year when it received its first covernment subsidy of \$333,333. In 1939 it received 5216,660. This organization was deliberately modeled after the American Meticanl Advisory Committee for Arronauties, for which the French had a greet admiration. Six members were high officials in the Air, Tavy and War "inlatrics; six were eminent scientists, and the remaining seven were the heads of the newly nations ized air industries. The official purpose

^{18. &}lt;u>Ibid</u>.
19. Ide, John J., "Some Technical levelopments in European Agramautics during 1931, 26 Jan 32. NACA Lib.

^{20.} Teport on Aviation Laws

^{21.} Peyronnet, R., in L'Intransiguant, Oct-Dec 35, resain 22. Ttr, John J. Ide to Dr. G. W. Lewis, 13 Dec 38 in MACA Lib.

^{23.} Ibid.

of the Association, as state by the Air Ministry and the Mational Society of Aeronautical Constructions also ruce primarity responsible for its creation, was "to promote and Lateunify in France studies, research, and experiments of any sort capable of advancing aeronautical techniques." 4

It was koped that of a wide collaboration of interested marties, and by a return assessment of meeds, the Ruspointion could assist the larving France in order to being itself in to dete. Three merel fields of activity care allested as times where research was lost needed. These were (1) word markes, (2) totors and funds, in' (7) feeting of experimental models. To initiate its work in aerodynamics, the Association made an a respect with the inferroit; of "life whereby that institution agreed to clace its famous Institute of Tyleaulies (Institut de Mecanique des riulas) largely at the disposal of the Association for this type of research, is the wor expanded, plans were made to utilize the resources of other laboratories. The studies previously carried but to develop new motors and fuels were considered insufficient to keep up with other countries. Therefore, it was planned to set un a special motor laboratory at Bricy, sear Orleans, to cerry out extensive experiments in this field. for the fest flyin; of her models, an experimental center was to be develoned near twinton where the salubrious climate promised a maximum of good flying days. Plually, to keen in the clastic develorments not only at have but abroad, the Association projected the establishment of an Aerotecarical Information Senter (Sentrale d'Information Aerotechniques) where re mais on the latest fleas and rethods so ld be classified and preserved.25

Unfortunately, jost of these excellent plans care to nothing because they were, in Light George's Panous phrase, "too little and too late". Thru flow to the thirties, France was confused and disorganised. The deep rilts between old and powerful parties that should have been bulmarks of the state became ever wider. The extreme 'eft and the extreme Right distrusted littler and feared him, but they lated each other rore, and the middle marties drifted first toward one side and then toward the other without finility a haven it either. The only common meeting mound of a majority of the people was a deep and sincere desire to avoid snother war, and as equally profound rejustance to amopare for it. 20 Part of this reluctance was, to doubt, strongly officated by mechanic factors, and none of the many ministries between 1933 and 1933 had the courage to propose the additional taxes which an extensive rearrament would inevitably require. An even more serious weakness was the over-confidence in the strength of the aringt ine which was frequently cited in opposing those who demanded more tan's and planes and higher taxes. The whole national psychology became sended to the fatel idea of a war based on a were holding of the inginot defenses and waiting to see what the enemy would do.

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

^{24.} Ibid. 25. Marophile, 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.

	(in france)	
	Germany	France
Technical services	122,220,000	44,500,000
Technical service	27,000,000	6,125,000 (27)

During the early years of the fitter regime, when Germany was making intensive and successful efforts to develop new and improved tanks, guns and airplanes, French covernments were reducing the amounts reserved for scientific investigation in the Kir Ministry budgets. Here again, the figures offer a strikeing testingly to the extent of French unpreparedness.

tir Sudget Excenditures in Millions of France

Year	Total bullet	Fescerch Junds
1933	1360	119
1734	134Ω	77
1905	2200	73
1936	23 CO	93
1737	<i>1,20</i> 0	150
1933	3200	3 4 0 (n#)

Towever, when the danger was at last herceived, and an ettempt was made to catch up with technical advances in aircraft, it proved impossible to throu off the confusion and sloth of many years accumulation. Furthermore, when the wer began, no sound policy of draft deferments was worked out and young scientists and technicians were ruthlessly snatched from their laboratories to sater an army that had made no provision for using their special skills as hadly needed elsewhere. In view of the French debacle, the statement of lines have, a dangerian journalist who served with the French Army in 1920-40, is of special importance.

I think there were two tainings, or three things that affected the French air power. The first thing was that the French air power was extremely outwooded. 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)

Tichnel I. 'cutch, a French engineer and economist, testifying about the same time ("ec. 1941), also hald great stress on the scientific and technological unpreparedness of France.

^{27.} Newout, ibid., ICT

^{28.} Figures cited in the oppoint articles in Matransineant.

^{29.} Henricas on 32721, II, 574, testimony of cans cabe, 10 Dec. 1942

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. Thatever 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.

ifinal consent must be made on another handicap that restricted the efforts of reach arrotatical science to entermy with its mere rapidly advancing seighbors. This was the unwillingness of the military and neval authorities to open up their secrets, take civilian scientists into their confidence, and live for no a idea of the technical employment of their discoveries. The invention of a device to mentralize the former magnetic nine, for example, was held up for some tile because the French navy recomes to give out a complete description of this weapon. Here is evidence of a serious gap between French actance and the French was rechine—a gap which the various scientific coordination and integration conditions can take to bridge. In an article in the Free Toric magnine, "one sign West Tarions" Center of Tractical Tesearch, presents a powerful indictment of the Torica Science.

In France, the research branches of the sened forces, until recent years firmly upheld the destrine that the military, having a marked superiority over the civilians in the imposed to of the weapons of mar, and their possible improvements, rust monopolize the study of the orderate technical problems of national defense. From these problems they must then extract the implied problems of pure science and give them over, in their arystalline unworldly purity, to civilian scientists to be studied as such only without any consideration of their application to military technique.

The structure was fought in France a minst this state of mind with its paralysing distinction between more and applied science; meason finally won out, but not a spletcly, and not until the last days of the war - too late, too late. This mental abbration chould be fought with ferrocity wherever it is met, because it always means against the paralysis against of the property of the research and it tooks against wictory.

In conclude, the brilliant beginnings of Tranch eviation before the first world man more not reintained during the intersor period. There were many reasons for this decline, but one of the nost i portant was the failure of French research to keep up with the latest aeronautical discoveries and experients in all a sountries. Trads provided by the government were

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hopelessly inadequate for research, especially in the period of the thirties. The paucity of money contrasts strikingly with the multiplication of research cosmittees and organisations. If anything, research in France was over-organised. There was little coordination between research agencies, and after 1930 the almost continuous reorganizations failed to establish any centralization. The really sincers 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 Pepublic. The research agencies were no exception to this trend, and during their last nine months of existence, during the devoralizing period of the "sitzkrieg", they were able to do nothing to halt the national disintegration.

Part H

RESDARCH AND DEVELOPMENT IN JAPAN, 1914-1939 1

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 recognised 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 Fast 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 rowe, 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 nost 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 Hanchuria.

The rivalry of Russia and Japan in Manchuria had precipitated their struggle in 1904-1905, 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 Sorld 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 Atlantie

^{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 test 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, firely adhered to, and 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 1919 Isunched out in a rapid remaining 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 and she bent her afforts. The United States lapsed into an atmosphere of pacifies 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 respectably high level. Japanese naval activity alarmed both Britain and the United States and the Washington Conference resulted. In bad grace Japan accepted mayal limitation; inwardly she considered the mayal ratio insulting. Thereafter much of her military activity was in the direction of increasing her already considerable air strength.

Research and Experimentation

Japanese wiliterists recognized that in general they had not been able to keep pace with the latest developments in wer machines and methods. While Germans, French, British, Italians, Bussians, and Americans had gained valuable experience with new weapons and devices under actual battle conditions the Japanese army and nevy had tended to stagnate. Too little was known of the use of tanks, poisonous gases, and mirplanese. 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 schetimes second 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 1919.

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. Fith 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 <u>muveau riche</u> who try to purchase culture. As a result of this nationalistic singlemess of purpose the povernment and industrial inboratories 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 raterials 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 so doing apparently suffered from an exaggeration of the bad points of each. Their work 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 <u>verboten</u>. 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 Investization 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 ras begun. By 1931 the Institute had fourteen buildings as well as possession of an unused railway tunnel some 800 yards long. Needless to say, research was largely along lines of military aeronauties.

Meanwhile extensive laboratories had been set up in army and navy arsenals. Aircraft factories, subsidized by the government, were equipped with hage laboratories manned by large numbers of scientists graduated from the Imperial universities, many of whom had also studied abroad. As airmindedness increased the aircraft industry grew, and laboratories were greatly expanded. Control over scientists became so taut 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 Gentral 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 attache 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 Japanese 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 attache reported that subjects of research at the Imperial University at Tokyo included: possibilities of aircraft without engines; superspeed nameras; Iray 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 mehogany, walnut, spruce, white cedar and pine. That their efforts were not successful is reflected in their hunc purchases of woods in the United States in the 1920's; flected in their hunc purchases of woods in the United States in the 1920's; ourchases which were no 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 the soya to take the place of castor oil. Japanese sought to obtain helium 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 ently they have not been able to approximate German successes in deriving fuel and lubricants from bases other than petroleum, nor in development fuel and lubricants from bases other than petroleum, nor in development alloys which do not require the use of i ported ores. Furthermore, their war equipment has shown an inability to reach western standards of craft—manshin and originality of design.

Aircraft Industry and Air Power

is in the case of research and experimentation the Japanese had neither time nor inclination to Japane upon their own products and resources for the development of an air force. Their original air force was purchased in its entirety. They turned to France as the leading exponent of land based air strength, and to Britain as the leading naval air power. A French military mission to Japan, comprising pilots, designers, rachinists 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 grench air force, differing chiefly in size. French made giveraft were purchased in large numbers; Trench 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 ways although some naval planes were bought from Jermany, Italy, Denmark, and the United States.

Thile this adoption of foreign material and nethods served as the fastest possible way to make Japan a great air nower, it was recognized that to maintain such a position the Japanese must be made airminded, and a domestic sincraft industry developed. Too often a foreign model would be out of date before planes could be delivered to Japane. Copying was supposed to be a nere stopper and the revernment took steps to out Japanese air power on a firmer basis.

By every possible propagandist means Japanese youth was made airminded; civil aviation was encouraged, residerable subsidies being granted to young men interested in learning to fly; subsidized commercial airlines were orojected and eventually put into preration; prizes were offered for accordishment in aviation; newspapers sponsored and publicized aerial commetition of various types; numerous air defense societies were organized.

Meanwhile for development of an aircraft industry proved a difficult task, Mitsubishi, Nakajima (backed by the Mitsubishi, Nakajima (backed by the Akura Commany), and Manasaki Dekyards (representing the extensive Jawasaki interests), were the most important aircraft manufacturers in Japan, tas 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 cajoled, bribed, or black-mailed into self-regimentation and into acquiescence to government control. Induced its in the form of promises of government contracts, out-right subsidies, exemption from income and a siness profit taxes and import duties on approved materials, all won them over and cave impetus to a rapid expansion of existing plants and the building of numerous others.

Financial assistance was given the injustry in so many devices ways that it is obviously immossible to make an accurate computation, but the amount was anormous. Government money at their dismosal in almost unlimited amounts enabled the industry to adopt a relatively migh wave scale which attracted labors. 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 & erican experts were imported to advise, teach, and direct the huge expension. In the meanwhile large numbers of Japanese were sent abroad to study production methods and techniques.

In their hasty develoment aircraft ranufacturers 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 Jamenese versions without consideration of patent rights. Filitary attache reports furing the period mention the following planes as either being ranufactured in Japan under patent rights or being conied without regard to patents: Harriot, Hansa, Fairey, Pohrbach, Fairehild, Heinkel, Junkers, Dlarson, Iornier, Iokker, Vought, Glouster, Curtiss, Nieuport, Brequet, Dewoitins, Lockheed, and Blackburn. Engines were: Hispano-Smiza, Salmson-LoPhone, Mapier, Renault, Gnome and Phone, Armstrong-Seddely, Cirrus, Pratt-Thiray, Tright, Jupiter, Tynx, Farman, Lorraine-Deitrich, BMW, Benz, Rolls-Royce, and Junkers.

By 1927 the industry had made such strides that factories no longer retained such large numbers of foreigners. Frantic efforts were being made to develor Japanese plane 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 lar; numbers, although each one could be immediately spotted as an imitation of nore foreign model. Most of the accessories, however, were still being imported: Stromberg, Renz, BMW, Zenith, and Claudel carburetors; Bosch, Lodge, and FLG spark plugs; Istonbe, Eclipse, Waywood, Mersmark, and Garelli starters; Beach and Scintilla magnetos; Lamblin, and Andre radiators; Vickers. Lewis, Totchkiss, and Oerlikon guns; Curtiss-Reed twisted blade proballers; propeller for ings from Warilton Standard Propeller Company; steel propeller hubs from Nethlehem Steel Corporation; Sperry automatic pilots; BMM squarchargers; SKF bearings from Sweden; Farmen reduction gears; and Hand sy-Page slotted winds. Approximately eighty per cent of the machine tools were of American ranufacture, and most of the remainder were made in Germany, but the Japaness were beginning to produce their own mac line tools. In the midthirties military attaches were excluded from most of the aircraft factories and from that time on little was known of their activities.

The bought-ready-rade Japanese air force by 1924 had become a source of anxiety to the United States. In that year General Billy Nitchell visited Japan, reporting that the Japanese were probably second only to France in air strength, and that they were far whenly the United States. This yap would be greatly videned, he said, because of the Japanese building program planned for the next two years. This 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 Wited States, the Cindings 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 mest nowers; it was of recent construction and considered as a whole was unequalled in quality by that of any other country. Furthermore, her pursuit planes were the equal of any in existence.

In 1924 the Japanese army air Force consisted equipped with planes manufactured in foreign countries. By 1935 it had been increased to 37 squadrons equipped entirely with planes manufactured in Japan but of foreign designs. Nost of them were already obsolespent, 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 thr number of squadrons was increased to 53 and many of the obsolete planes retired. A new valley with regard to adoption of clane types was being followed. Instead of ordering large numbers of a particular model and having it become obsolusiont before production was completed they began to order smaller maders, placing orders at a re-frequent intervals. In this may the air force was equipped with fewer and fewer obsolete planes. By 1937 the air force was swalled to 59 squadrons, of whice 21 were pursuits, 16 observation, Il light and medium borbers, and 4 heavy borbers. We attack aviation tall been adopted. From 1937 on the Japaness air force gree rapidly, and considerable monowers twas noted in their aircraft. While sume of the newer less us 15th have been peciliarly Japanese, others were of Jerman orlight.

Jagmese 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 accented in other countries. As the industry tree, however, pilots were taught that aircraft so ld be procured in such numbers that they could be used without retard to losses — the mission itself was all-important, not the return of sircraft and pilots.

Chins provided Japan with an excellent proving ground for both material and taction as long as their here andigh notern planes in China to oppose them. As the Chinase air fince became imposs to the Japanese used only see number planes and pilote, keeping the better forces in Japane. Levelorments within their air force were kept secret, a flack result incricens have bed in Jean about the name way — in corbet aminut them.

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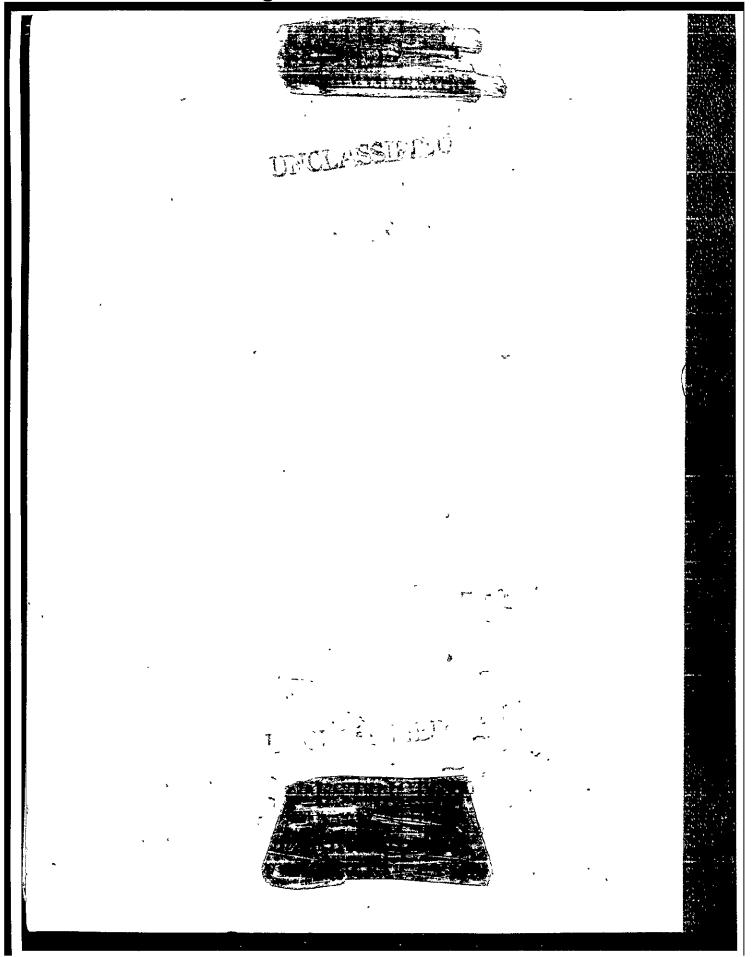
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