UNCLASSIFIED

AAF HISTORICAL STUDIES: NO. 50

MATERIEL RESEARCH AND DEVELOPMENT IN THE ARMY AIR ARM

1914 – 1945

AAF HISTORICAL OFFICE
HEADQUARTERS, ARMY AIR FORCES

UNCLASSIFIED

[redacted]

UNCLASSIFIED

ARMY AIR FORCES HISTORICAL STUDIES: NO. 50

MATERIEL RESEARCH AND DEVELOPMENT IN THE ARMY AIR ARM

1914-1945

AAF Historical Office
Headquarters, Army Air Forces
November 1946

[redacted]

[redacted]

UNCLASSIFIED

FOREWORD

This study of materiel research and development in the Army air arm, 1914-1945, was prepared by Dr. Martin P. Claussen. An earlier version of the study was a part of a larger work entitled "Comparative History of Research and Development Policies Affecting Air Materiel, 1915-1944," prepared for the Scientific Advisory Group of the Office of the Chief of Air Staff.

The relationship of the Army air arm to the vast cooperative effort of "science at war," particularly in the years since 1939, is the chief emphasis of the history. As stated in the introduction, the study deals with "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; the expansion of the AAF establishment for experimental engineering and for research control, 1939-1944; and the changing relationships of the AAF to the wartime research activities of the federal government, the other supply services, their industrial and university contractors, and the research stations of the other Allies."

Readers familiar with the subject matter are invited to furnish the AAF Historical Office with criticisms, additional facts, or interpretations. For this purpose, perforated sheets have been inserted at the back of the study.

[redacted]

[redacted]

CONTENTS

[redacted]

[redacted]

UNCLASSIFIED

ILLUSTRATIONS

Graph

Tables

[redacted]

[redacted]

UNCLASSIFIED

Materiel Research and Development in the Army Air Arm, 1914-1945

UNCLASSIFIED

[redacted]

[redacted]

UNCLASSIFIED

Chapter 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.[1] In twentieth-century air warfare this historical truth is particularly pertinent, chiefly because of the rapid rate of obsolescence of military airplanes since 1914, during a period when international rivalry, growing commercial competition, and other pressures stimulated the development of airframes with better airfoils, power plants with better performance, and equipment with greater precision and effectiveness.

The principle that the quality of the air force's airplanes must precede the quantity was not always universally accepted in the United States. In the early 1920's "there was a great deal of criticism of the Army and Navy for spending too much money on experimental work and

---

1. 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 (Boston, 1943; originally published in England); George T. Gray, Science at War (New York and London, 1943); and portions of J. D. Bernal, The Social Function of Science (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 National Archives Building, Washington D. C.

[redacted]

not enough on quantity procurement."[2] Army air spokesmen, saddled with an inventory of rapidly obsolescing 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 (on which the Army would depend in any national emergency) would atrophy.[3] Similar warnings were echoed and amplified by the epidemic of congressional and Army committees and boards that investigated the air arm between the 1918 Armistice and 1935.[4] Even with such repetitive hammerings at legislative and Army opinion,[5] the need for continuous research and development as a basic premise of air supremacy was not always unanimously

---

2. Report of the Federal Aviation Commission (Howell Commission), Jan. 1935, p. 127. The Howell Commission went on to say that then, in 1935, "the Services are in danger of switching to the opposite extreme." Ibid.
3. Memo for Maj. Pettis, OASW, by Gen. Mason M. Patrick, Chief of the Air Service, 28 Feb. 1923, in AAG 475.73, Aeronautical Equipment. 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.
4. These committees and boards are listed in the Final Report of War Department Special Committee on Army Air Corps (Baker Board), 18 July 1934, pp. 4-5. A subsequent board, the Federal Aviation Commission (Howell Commission) in 1935, should be added. These and other legislative committee activities, 1907-1935, are discussed in AAF Historical Studies: No. 25, Organization of Military Aeronautics, 1907-1935 (Congressional & War Department Action), passim.
5. For example, the Howell Commission in January 1935 (in its Report, pp. 157-58) had said that if a reduced Air Corps 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.

[redacted]

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.[6] 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 "Failure [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."[7]

The scope of "research and development" was rather broad in Army terminology. It was a phrase to denote the experimental activities of the Air Corps, and it was a budgetary rubric common to all the supply services of the Army in 1939. Essentially it meant (for the Air Corps) the engineering, research, and testing at Wright Field in connection with the construction by industry of new or improved models of airplanes, engines, and airborne and ground equipment peculiar to air operations. It was occasionally subdivided by the Air Corps, in the directives and

---

6. Materiel Div. memo, "Aeronautical Research and Development" [about 24 April 1939], in AAG 400.112, Tests and Experiments. The wording is slightly different in the final draft of "Air Board Report," AG 320.2 (6-26-39), 15 Sep. 1939, Tab C, p. 2 (mimeographed copy in A. J. Lyon project book no. 15-A, in Office of Deputy AC/AS, M&S).
7. Ibid., Tab C, "Policy Governing Research and Development," p. 1. The observation on production requirements, which was omitted from the final draft of the report, appeared in a memorandum of proposed recommendations of the Board, [about May 1939], in AAG 400.112, Tests and Experiments.

[redacted]

correspondence, into "fundamental research," such as aerodynamic analysis in wind tunnels, and "applied research."[8] Neither of these subheadings was exclusive, however, nor was the distinction always accurate. For example, wind-tunnel tests, far from being studies in "pure science" on the theoretical aspects of air behavior, usually were applied tests of scale or full-scale models of wings or other airplane surfaces. Nor was aerodynamics the only problem involved in research and development. The development of new aerial weapons in total war potentially included research in all the natural and physical sciences, in both their "pure" and their "practical" phases. The Air Corps, however, made no distinction in actual practice, in the administration of its research activities, between these two arbitrary divisions of science; and in ignoring such classifications of knowledge Air Corps officials apparently did not betray any more uncertainty and unrealism than did the scientists themselves.[9]

---

8. Other Air Corps classifications in 1939 were "fundamental" (NACA), "applied" (Wright Field), and "university" research, entirely omitting industry. (Materiel Div. memo, "Aeronautical Research and Development" [about 24 April 1939], in ibid.)
9. For example, in a survey of the scientific activities of the federal government and their relation to industrial and university research, made in 1937-1938 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 four instead of the traditional two 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 (H. Doc. No. 122, 76 Cong., 1 Sess.); as well as later volumes on Industrial Research and on Business Research.

[redacted]

More important than a pigeonholing or compartmentalizing of research and development was the fundamentally cooperative character of science, in war (as, indeed, of science in peaceful pursuits). Especially was this true of experimental airplanes, whose complex design and construction problems had been aptly summarized shortly before by the Federal Aviation Commission:[10]

> 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 National Advisory Committee for Aeronautics (NACA) and Wright Field, flight and static test reports from Wright Field, operational suitability tests from the Air Corps proving ground,[11] suggestions for modification from the tactical units of the

---

10. Howell Commission, Report, 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 given aircraft firm.
11. That is, the 23d Composite Group, activated at Maxwell Field, Ala., in August 1939 and moved to Eglin Field, Fla., in December, and an "ancestor" of the AAF Proving Ground Command. See PGC Historical Branch, "Historical Outline . . ." (Jan. 1945), pp. 19-20.

[redacted]

Air Corps and (after December 1941)[12] from the overseas theaters of operations, and the suggestions from the Allied air forces. Furthermore, especially with respect to related bombardment, armament, communications, reconnaissance, navigation, and other airborne and ground equipment, the sources of ideas and experimentation included still other agencies, such as the other Army supply services (Ordnance, Signal Corps, etc.) and 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: 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; the expansion of the AAF establishment for experimental engineering and for research control, 1939-1944; and the changing relationships of the AAF to the wartime research activities of the federal government, the other supply services, their industrial and university contractors, and the research stations of the other Allies.

The basic scientific resources for developing better weapons, as discussed in this study, consist of (1) scientific personnel,

---

12. Actually, suggestions for modifying airplanes and equipment had already been coming in to Wright Field much earlier than America's entry into the war in December 1941. The various Air Corps observers in 1940-1941, including the Air Officer of the Chaney Mission (Army Special Observer Group) after June 1941, were concerned in large part with analyzing the combat performance and effectiveness of U.S.-produced air materiel (both Lend-Lease and British-imported); and their reports were of course transmitted to the United States for use by the Air Corps and its industrial contractors.

(2) laboratory and experimental facilities and equipment, (3) money, (4) organization and administrative framework, and (5) a favorable public opinion. Still another category might be (6) the recorded intellectual experience, whether buried in publications, archives and records, or unpublished manuscripts. If there is any truth in the assertion that "no new idea is really new," this truth stemmed in part from the fact that many recorded ideas lay buried and dormant, for the most part, in the archives and libraries of science and technology. For example, in 1939, at least 33,000 scientific periodicals were being published throughout the world,[13] and their utilization was far from adequate either for peacetime or for wartime purposes. Even abstracts of this literature, like Chemical Abstracts, were not being fully utilized. Added to this were the mountains of unpublished manuscripts in academic, industrial, and governmental files, including the historical files in such repositories as the Library of Congress and the National Archives. Even the systematic Germans were probably not ferreting out every last idea of military value from their own archives. In the United States, it was said in 1939, "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."[14]

---

13. World List of Scientific Periodicals (1934 ed.). Problems of scientific publications are discussed critically in Bernal, The Social Function of Science, pp. xv, 117-18, 272 ff., 292 ff., 449-57.
14. National Recources Committee, Relation of the Federal Government to Research (1939), p. 53.

[redacted]

Chapter II

RESEARCH AND DEVELOPMENT POLICIES IN WORLD WAR I

Industrial Research by 1914

By the eve of World War I industrial research had come to have a respectable position in America's growing corporate economy. Edison's plant at Newark, N. J., established in 1869, and his Menlo Park Laboratory, in 1876, had been the first outstanding early example of applied research for industrial exploitation. At the same time the General Electric Company since about 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 sewing machine, the reaper, and the typewriter, to cite only a few outstanding examples. Between 1890 and 1914 laboratories became a common adjunct of industrial firms, but with a fluctuating "birth rate," as shown in the graph on the following page.[1]

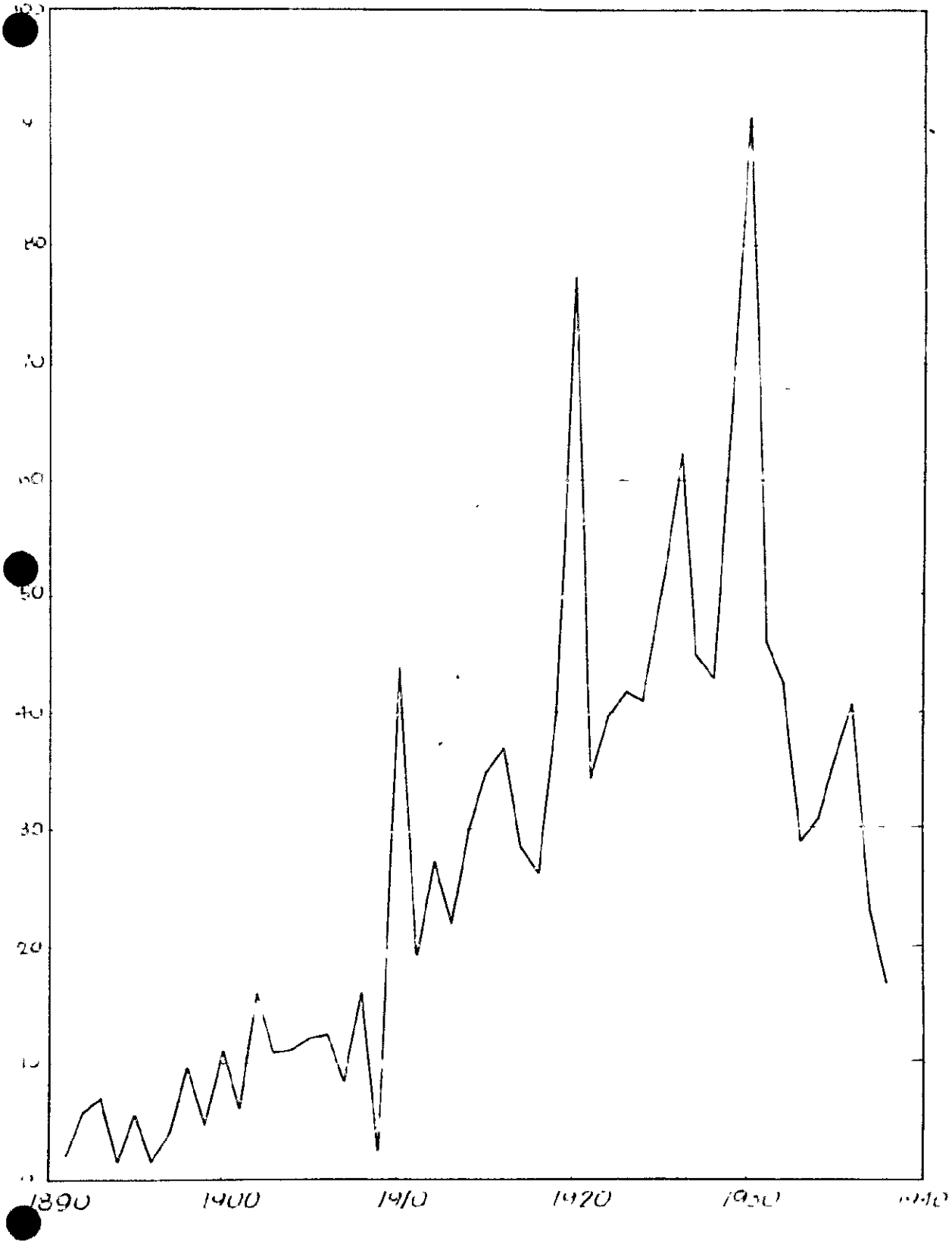
Industrial research was motivated by profit, of course, and had flourished in industry before 1914 largely because of the growing appreciation that better or new products would command a better market in the competitive world. Sometimes this motivation had an adverse

---

1. Graph taken from 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 National Resource: II. Industrial Research (1941), p. 176.

[redacted]

[redacted]



THE "BIRTH RATE" OF INDUSTRIAL RESEARCH

[redacted]

effect on the exploitation of inventions[2] 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.[3] But in general, corporate research was performing a useful social function that had a potential for both peaceful and wartime pursuits.

Among the customers for industrial research was the military. In some outstanding cases Army and Navy support to research--government subsidies, in effect--had been the chief reason for the immediate development of a field of applied science. The development of large-scale smelting of iron with coal, the steam engine, and the Bessemer process all had resulted directly from military and naval needs;[4] and in America the Navy had substantially influenced the growth of the steel industry after 1883, and the Army the chemical industry after 1891.[5]

Aeronautical Development by 1914

Aeronautics by 1914 was the latest field where scientific development was being financially sponsored primarily in connection with war

---

2. No history of inventions can be included here, although the literature on the subject is substantial. Inventions, of course, derived also from sources other than industry research. For example, only 12 out of 75 of the most important inventions between 1889 and 1929 came out of corporate laboratories, according to one critic, J. D. Bernal, in The Social Function of Science, p. 161.
3. Hearings conducted by Louis D. Brandeis, 1912, quoted in Bernal, The Social Function of Science, p. 143.
4. Bernal, The Social Function of Science, pp. 165-70. Bernal, a critic in 1939 of the "prostitution" of science to war, acknowledged that the "majority" of technical and scientific advances in the nineteenth century had sprung from military and naval needs (ibid., p. 165).
5. National Resources Committee, Relation of the Federal Government to Research, pp. 44-45.

[redacted]

and national preparedness, but it was in Europe rather than in America where most of the official interest in military aeronautics lay. The War Department appropriation for aeronautics in 1914 totaled only $125,000, vastly less than that of any of the major European powers, and less even than the appropriations of 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.[6] Furthermore, in 1895 it had been the Army and Navy that were most sympathetic to Samuel P. Langley's scale-model "Aerodrome" and that gave him a partial subsidy for building a full-scale model of the flying machine. In 1903, however, when Langley's machine failed to launch, the newspapermen who were present damned the project with sarcasm and ridicule, and the War Department chose not to take an independent view and continue its development. In the same year, the Wright brothers' first flight at Kitty Hawk, N. C., brought little response from the public, and apparently none from the War Department. In 1905 an offer by the Wrights to sell their plane to the government was rejected, and not until after they had sold their ideas in France, Britain, and Germany did the War Department become interested. The crash in 1908 of the Wright model being tested for the Army at Fort Myer, Va., did not this time deter the Army, however, and in 1909 the Wright "A" pusher was accepted from the Wright brothers.[7]

---

6. Frederick S. Haydon, Aeronautics in the Union and Confederate Armies, With a Survey of Military Aeronautics Prior to 1861 (1941).
7. Draft AFCHO study, "A Brief History of the Army Air Forces," especially pp. 23-24, 29-32.

[redacted]

These modest beginnings were followed by additional purchases of airplane models from the Wrights, as well as from Curtiss, Burgess, and Martin, totaling about 39 pusher and tractor airplanes delivered to the Army by the end of 1914.[8] None of these models had been "custom built" for any tactical use, although in 1914 the first American specification for a military plane had been issued.[9]

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 $35,000,000 spent between 1908 and 1913 throughout the world for military and naval aviation, only $435,000 had been spent by the United States, less than that spent by any other major power and less even than the expenditure of various minor powers, as shown in the table below:[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
Bulgaria	600,000
Greece	600,000
Spain	550,000
Brazil	500,000
United States	435,000

8. Tabulation, "U. S. Army Airplanes Accepted from 1908 to January 1, 1919," n.d., in A. C. Historical Section file 452.1, Airplanes, General.
9. Arthur Sweetser, The American Air Service . . . (1919), p. 25.
10. Ibid., p. 16, quoting testimony before House Committee on Military Affairs in 1913. Figures published by the NACA in 1943 vary slightly: Germany, $32,000,000; France, $25,000,000. (Journal of Applied Physics, Aug. 1943, p. 399.)

[redacted]

If the government was parsimonious in subsidizing aviation development, commercial sponsorship of aviation was even less substantial, if not totally nonexistent. There simply were no significant commercial outlets for aviation in 1914; "the meager aircraft industry had only one customer, the United States Government."[11] Stated in terms of aeronautical progress rather than aeronautical budgets, America's position was equally inferior, as reported officially in 1913:[12]

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

In contrast, the most hopeful sign for American aviation in 1914 was that organized aeronautical research had been begun. In 1913 the first steps had been taken to establish the National Advisory Committee for Aeronautics, and in 1915 it was given its first appropriation for the "scientific study of the problems of flight." These origins of the NACA have been described as follows:[13]

> In 1913, Dr. Charles D. Walcott, then Secretary of the Smithsonian Institution and a member of the National Academy of

---

11. Statement by NACA, in Journal of Applied Physics, Aug. 1943, p. 399.
12. Sweetser, The American Air Service, pp. 18-19, quoting an unidentified "official" report of 1913.
13. Official view of the NACA in August 1943, in Journal of Applied Physics, Aug. 1943, pp. 399-400.

[redacted]

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. ... I. Chambers, Glenn Curtiss, Orville Wright, Dr. Walcott, and officers of the Army and Navy. Only three meetings were held when the Comptroller of the Treasury . . . [ruled] that the committee could use no government funds nor personnel because it had not been established by law. So the life of the Advisory Committee of the Langley Aerodynamical Laboratory ended.

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

Finally, however, Dr. Walcott succeeded in getting his bill attached as a rider to a Naval appropriation bill, which was passed by Congress and became law March 3, 1915, and the National Advisory Committee for Aeronautics was created—"for the supervision and direction of scientific study of the problems of flight, with a view to their practical solution" and to "direct and conduct research and experiment in aeronautics."

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

Wartime Research and Development, 1914-1918

The National Advisory Committee for Aeronautics, although it dated officially from 1915, did not acquire any laboratory facilities early enough to use in the war that followed. In April 1917, when war was declared, its facilities were still in the planning stage: four months earlier it had been promised a portion of the proposed Langley Field (Va.), selected by the Army as its own testing area as well. And the end of

[redacted]

the war in November 1918 came before the first NACA wind tunnel could be completed and before its new engine dynamometer buildings could be put into operation. Actually, the wartime research activities of the NACA were less prominent than was its advisory work on other aeronautical matters--production planning, standardization, patents, and training.[14]

Nor had the Army's own experimental facilities passed the planning stage in April 1917. Langley Field 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."[15] The Aviation Section's "Engineering Organization" in Washington, consisting, early in 1917, of Capt. V. E. Clark and five civilian engineers, 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."[16]

---

14. NACA, Annual Report (1919), pp. 13-14; and Lt. Robert C. Hilldale, "History of . . . Aircraft Production . . .: Advisory and Co-operative Agencies" (Air Service historical monograph, about 1919), pp. 1-37, in A. S. Historical Section files. Another function, that of "aeronautical intelligence," was established in 1918 for the collection and dissemination of information on American and foreign aeronautical developments, and included a "scientific attaché" in Paris.

15. Site selection, construction, and jurisdictional disputes between the Bureau of Aircraft Production and the Directorate of Military Aeronautics are all discussed in Capt. H. H. Blee, "History of Langley Field" (Air Service historical monograph, 18 Aug. 1919), in A. S. Historical Section files; copy also in AFSHO.

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

[redacted]

As the alternative, the McCook Experimental Field at Dayton, Ohio, was selected in 1917 because of its proximity to the airplane industry in that city and to the automobile industry in neighboring states, although some public critics later charged that the site had been selected by Col. E. A. Deeds, Dayton industrialist in the Air Service, because of his airplane and other interests there. Some important laboratory facilities were built at McCook before the end of the war, including dynamometer buildings; a propeller test laboratory; a nine-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.[17] By November 1918 the experimental engineering personnel of McCook Field totaled 14 officers and 1,335 civilians.[18] The Experimental Engineering Department, under Lt. Col. Howard C. Marmon (ex-Nordyke-Marmon), was kept quite separate from the Production Engineering Department located in downtown Dayton, although both the experimental and production phases of the Air Service came under the Airplane Engineering Division headed by C. W. Nash (ex-General Motors) and Lt. Col. J. G. Vincent (ex-Packard). These agencies in turn were part of the larger Bureau of Aircraft Production, set up separately

---

17. 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 360.05, McCook Field.
18. Compared to production engineering, which had 26 officers, 330 civilians; and "business and military," which had 18 officers, 250 civilians, and 267 enlisted men. See historical questionnaire, 7 May 1919, returned by Engineering Division, in A. S. Historical Section file 360.05, McCook Field.

[redacted]

from the Signal Corps in May 1918 and headed by John D. Ryan (ex-Anaconda).[19]

The industrial backgrounds 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, which underscores the fact that in 1917 there was no substantial aircraft "industry" on which the Army could rely.[20] The airplane and airplane engine industry consisted of only 11 firms; its total capitalization was only $15,000,000, of which over two-thirds was controlled by two firms--Curtiss (airplanes) and Wright-Martin (engines); and the whole industry could muster only 8,000 workers, skilled and unskilled, early in 1917. The Army's total purchases of planes had been 39 up to the end of 1914 and 224 up to April 1917, but as yet these deliveries had not included any models designed entirely for a military use. As of early 1917, no "battle planes" had been built in the United States, and "only a handful of Americans had ever seen one."[21]

---

19. Organization chart of Airplane Engineering Division, Bureau of Aircraft Production, Nov. 1918, in A. S. Historical Section file 360.05, McCook Field. After the Armistice, about March 1919, materiel functions were reorganized into the Engineering Division (Col. Thurman H. Bane, chief), which was a consolidation of the Bureau of Aircraft Production and of the Technical Section of the Director of Military Aeronautics. A small "Supply Group" was established in Washington about the same time. (Engineering Division, Annual Report, 1919, p. 1; copies in War Department Library and in AFSHO.)

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

21. Tabulation, "U. S. Army Airplanes Accepted from 1908 to January 1, 1919," in A. S. Historical Section file 452.1, Airplanes, General; Edgar S. Gorrell, The Measure of America's World War Aeronautical Effort (1940), p. 2; and Sweetser, The American Air Service, pp. 45, 189, 251-52.

[redacted]

The source for airplane design data in 1917 was, therefore, not American industry but the Allies in Europe, where combat-type planes had already seen action. Maj. R. C. Bolling was sent to England, France, and Italy in June 1917 with a mission to select models and to obtain data and samples of materiel.[22] Accompanying him were several Army and Navy aeronautical engineers and engine experts and 93 representatives of the industry. Four chief models were agreed on, between the United States and the Allies, for production in the United States: the De Havilland combination fighter and day bomber, the Handley-Page night bomber, the Bristol fighter, and the Caproni bomber. Of these, the first two models were to reach quantity production before the Armistice.[23]

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 the Armistice came in November 1918. Most of the experimental airplane work at McCook Field in 1917 and 1918 was concerned with modifying European models to adapt them to American production, a production engineering job rather than one of experimental engineering.

---

22. See R. M. McFarland, ". . . History of the Bolling Aeronautical Mission" (A. S. historical monograph, 29 Oct. 1919); copies in AFSHO files and in A. S. Historical Section file 334.8, Bolling . . . Mission.
23. Hilldale, "History of . . . Aircraft Production . . .: Advisory and Co-Operative Agencies," pp. 113-20 and Appendix; Sweetser, The American Air Service, pp. 64-65, 191; and Gorrell, The Measure of America's World War Aeronautical Effort, p. 3.

[redacted]

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 Washington, in five days in May and June 1917 is only partially correct. Actually it was the product of cooperative enterprise over several months, including also the work of many engineers from several other automobile firms and from the National Bureau of Standards.[24]

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

Supervising this research program was the Science and Research Division of the Signal Corps (after May 1918, a division of the Air Service), headed by two civilian scientists in uniform--Dr. (Lt. Col.) Robert A. Millikan and Dr. (Maj.) C. E. Mendenhall.[25] This group, which

---

24. "History of the Bureau of Aircraft Production" (A. S. historical monograph), microfilm copy in AFSHO; and Sweetser, The American Air Service, pp. 176-77.

25. See the following Air Service historical monographs: "Science and Research Division" [about Dec. 1918]; "A Brief History of the Organization and Activities of the Science and Research Department of the Bureau of Aircraft Production" [about 1919]; and Hilldale, "History of . . . Aircraft Production . . .: Advisory and Co-Operative Agencies," pp. 55-74. (A. S. Historical Section files.) See also National Research Council annual reports, in National Academy of Sciences, Annual Report (1917), p. 47; ibid. (1918), pp. 70, 105.

numbered 22 officers, 120 enlisted men, and 16 civilian scientists by November 1918, had originated in 1917 in the Physics Committee of the new National Research Council (NRC).[26] 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.

Postwar 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 postwar years. By the end of the war the McCook Experimental Field had become an effective center for postwar research and development, and by 1919 the NACA's first wind tunnel, financed by wartime appropriations,

---

26. The National Research Council, apparently inspired by several civilian scientists and engineers connected with the National Academy of Sciences, was established in 1916, with White House approval, to make the scientific talent of the nation more directly available on problems of national preparedness. Its establishment, one year before America entered the war, compares favorably with its British counterpart, the Department of Scientific and Industrial Research, which was organized in 1915, one year after Britain entered the war.

[redacted]

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 1919; $11,302,266 was expended on experimental projects during the whole wartime period from 1917 through June 1919.[27] These expenditures were exclusive of additional sums such as the pay of military and civilian personnel, and were invested chiefly in the laboratory facilities and equipment at McCook Field and in a substantial inventory of experimental models of airplanes and equipment. Notable were the following experimental combat models, built before the Armistice but not in production by then:[28]

Ordnance D	1-place "service" airplane
Stout monoplane	1-place "service" airplane
Lepere 11	2-place observation
Lepere 12	2-place fighter
Loening	2-place fighter
Thomas Morse MB-1 and MB-2	2-place fighter
Thomas Morse MB-3	1-place pursuit
Curtiss biplane	2-place pursuit
Curtiss triplane	3-place pursuit
USB-1 and 2	fighters, based on British Bristol
USD-9A and B	fighter-bomber, based on British DH-4
Glenn L. Martin	bomber, 2-engine
J. V. 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

---

27. The total expenditures of the Air Service (materiel, training, pay, etc.) were $1,047,107,458, out of appropriations totaling $1,691,854,758. Gorrell, The Measure of America's World War Aeronautical Effort, pp. 8-9.
28. Tabulation, "Comments on Principal Airplanes Considered for U. S. Army Use During the War of 1917" [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.

[redacted]

rather than to standardization and production: the design, and in some cases actual construction,[29] of experimental pursuit, attack, and observation planes; studies and layouts of other planes for night bombing, night attack, ground attack, and infantry liaison; work on air-cooled engines, cooling systems, and superchargers; and testing (and sometimes independent designing) of parachutes, leakproof tanks, photographic equipment, radio, aerial torpedoes, armament, and bombing equipment.

Postwar experimental activities between 1919 and 1923[30] were especially significant in view of the severe budget retrenchments beginning in 1919, the growing indifference toward national preparedness by the general public, and the increasing pressure for production standardization from higher authority in the Army. On the latter situation, the Engineering Division was faced with resistance from Washington, surprisingly from higher authority within the Air Service itself. On a bombsight development problem, for example, the Supply

---

29. A total of 27 airplanes were actually designed and built at McCook Field, including the following:

Bombers:	USA-D-9, 9A, and 9AB; XB-1A (12 articles)
Attack:	GA-1 (2 articles)
Pursuit:	PW-1, 1A; TP-1; TW-1; USA-C1; VCP-1 (8 articles)
Observation:	CO-1; CO-2 (4 articles)
Racer:	R-1 (1 article)

(Engineering Division Rept. No. 2100, 22 Jan. 1923, "List of Air Service Airplanes, April 1917 to November 1922," in AAG 452.1, bulk files.)

30. The Engineering Division published a secret report on 1 Nov. 1923, entitled "Special Report to the Service," which is virtually an encyclopedia of all air materiel under development at that time. (Copy in A. S. Historical Section files.)

[redacted]

Group in Washington had this to say late in 1921 on the issue of production versus experimentation:[31]

> 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 equipment.

Commenting on the same general problem shortly thereafter, the Chief of the Engineering Division complained to Col. H. E. Wimperis, the British bombsight pioneer, that experimental work in America was suffering in the postwar period:[32]

> 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 near the moment of the nation's greatest financial "exhilaration." Nevertheless, a small nucleus of officers and civilians did survive. 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

---

31. Memo for Engineering Div. by Acting Chief, Supply Group, 3 Oct. 1921, quoted in draft ATSC historical study, "Development of Bombing Equipment," Chap. III, p. 5.
32. Chief, Engineering Div. to Col. H. E. Wimperis, British Air Ministry and Imperial College of Science, 17 Feb. 1922, quoted in ibid., Chap. II, p. 8.

[redacted]

"visionary" project and negotiate with Boeing for design data for the heavy and long-range bombers. This peacetime research and development program for bombardment, begun six years before the European war and eight 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 materiel when America became the "arsenal of democracy" in 1940, and when the Army Air Forces went into combat in 1941.

[redacted]

Chapter 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 materiel was "equal or superior, with few exceptions, to that of any other nation,"[1] no longer applied. The Technical Staff at Wright Field in August 1939 had estimated American aviation as inferior to that of the foreign air forces, and while applauding any world progress in aeronautics "from a purely scientific view-point," labeled 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.[2] This Air Corps view had been supplemented by public warnings from other leadership in American aviation, including Dr. George W. Lewis and Dr. Vannevar Bush of the National Advisory Committee for Aeronautics,[3] and Theodore P. Wright of the Curtiss-Wright Corporation.[4] While most of these estimates were phrased in terms of "warnings"

---

1. Baker Board, Report, p. 72; Howell Commission, Report, p. 127.
2. ESMR No. 50-461-351, 18 Aug. 1939, "Future Aeronautical Research and Developmental Problems," prepared by E. Kotcher, Technical Staff, in M&S file on "F.Y. 1941 R&D Program."
3. New York Times, 10, 13, 18 Jan. 1939, 15 June 1939.
4. Ibid., 26 Jan. 1939.

[redacted]

by advocates, properly intended to provoke support for expanded aeronautical research, the fundamental accuracy of their indictment of Army air materiel is not challenged in any Air Corps correspondence and records used in this study.[5]

In terms of models on hand in September 1939,[6] the standard combat airplanes in actual tactical use in September 1939 had all been in production since 1936 or 1937: the Douglas B-18 two-engine bomber, 1937; the Northrop A-17 one-engine attack, 1937; the Seversky P-35 pursuit, 1936; and the Curtiss P-36, 1936.[7] In terms of developmental airplane models on hand, the Air Corps position was equally critical. Of the 14 "experimental" models on hand, only two were new airplanes built and

---

5. In 1934-1935, 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 Howell Commission, in its Report in January 1935 (p. 127), had criticized the recent "incessant attack . . . upon the [hopelessly inferior] quality of American military aircraft," "using every available medium of publicity," while similar self-critical attacks were under way "in the very countries [especially Great Britain and France] which [had] been held up to the United States as examples to imitate." The Baker Board had also scored the legend of American inferiority, based on a "fear . . . industriously cultivated in this country by various zealots" (ibid., p. 10).
6. For the inventory of all adopted, developmental, condemned, and obsolete planes in September 1939, see "War Department Special Quarterly Report of Airplanes: Status of Regular Army, Organized Reserve, and National Guard Airplanes," 30 Sep. 1939, passim. (Copy in AFSHO.)
7. Total airplanes of each model on hand in September 1939: 218 B-18's, B-18A's; 202 A-17's, A-17A's; 68 P-35's; and 171 P-36's, P-36A's, P-36B's, P-36C's. (Ibid.) Production dates above are taken from various editions of characteristics and performance charts, 1937-1939, passim.

[redacted]

delivered during the year[8]--the North American XB-21 with turbo superchargers and power turrets;[9] and the Stearman XA-21 attack bomber.[10] Of the total of 24 developmental models (both "experimental" and "service-test") on hand in September 1939,[11] only five were assigned to Wright Field for experimental work; and, except for the XB-21 and the XA-21, they were actually "old" as to their construction date or their close similarity to older, standard models:

XB-21	medium bomber (North American), 1939;
XA-21	attack bomber (Stearman), 1939;
YlB-17A	heavy bomber (Boeing), similar (except for engines) to XB-17 of 1935;
XP-37	pursuit (Curtiss), built in 1937 and based on older P-36;
XP-41	pursuit (Seversky), built in 1939 and based on P-35 of 1936;
XFM-1	pursuit (Bell), built in 1937;
XC-35	transport (standard Lockheed "Electra"), modified in 1936 for use in high altitude pressurized cabin research.

---

8. A later statement by the AAF (Hq., MC, memo, "Research and Development in the AAF," prepared by "Maj. D." [about Feb. 1943], in M&S Development Engineering Branch file, 700.430 Kilgore Committee--Office of Technological Mobilization), that only "a single experimental airplane" was delivered in 1939 seems, therefore, to be in 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 chart, "Characteristics and Performance of U. S. Army Airplanes," 1 July 1939, Sheet A, copy in AFSHO.
9. Other characteristics of XB-21: 2 Pratt and Whitney R-2180 engines, each 1,400 hp, 14 cyl.; span 95', length 61'9", height 14'9"; weight 19,080/27,255 lbs.; speed 195/220/-mph; climb 10/10,000'; ceiling 25,000/-'; range 1,950 miles; bomb load, 4000 lbs.; 5 x .30 machine guns. (MD chart, "Characteristics and Performance of U. S. Army Airplanes, 1 Jan. 1940.
10. Characteristics of XA-21: 2 Pratt and Whitney R-2180 engines, each 1,400 hp, 14 cyl.; span 65', length 53'1", height 14'2"; weight 12,760/18,257 lbs.; speed 230/257/- mph; ceiling 20,000/-'; range 720 miles; bomb load, 2,000 lbs.; 6 x .30 machine guns. (Ibid.)
11. Twenty-four models, totaling 62 airplanes; there was more than one article of some of the models. "War Department Special Quarterly Report of Airplanes . . .," 30 Sep. 1939.

[redacted]

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.[12] 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] This total inventory reflected in large part the budgetary situation of the Air Corps. As explained later in retrospect, "so large a proportion of the meager funds allotted [that is, $3,574,290 for research and development, fiscal year 1939] were needed for [the] applied research 'plant overhead' [at Wright Field] that the completion of a single airplane [or two?] was all that was possible in 1939."[14] Once the budget was increased, to $10,000,000 in the new fiscal year, the relatively fixed plant overhead, while still considerable and not static, permitted "half a dozen . . . complete airplane projects [to be] under development at Wright Field."[15]

In comparative performance, the best of these combat models were (except for attack planes) trailing the performance of foreign-developed models, especially the German. The best-performing Air Corps pursuit,

---

12. The XB-15 was assigned to the GHQ Air Force; the XP-40, to "miscellaneous." (Ibid.) Dates are from MD chart, "Characteristics and Performance of U. S. Army Airplanes," 1 July 1939, copy in AFSHO.
13. The XB-19 "flying laboratory" completed the list of experimental planes on contract. Ibid.
14. Hq. MC, memo, "Research and Development in the AAF," prepared by "Maj. D." [about Feb. 1943], in M&S file, 700.430 Kilgore Committee--Office of Technological Mobilization.
15. Ibid.

[redacted]

the XP-37 (340 mph) was, judging by the Kilner Board evaluation in June 1939, far behind the German Me-109E (469 mph) and He-112U (440 mph), but not far behind the British Spitfire (362 mph), and ahead of the Italian Mc-200 (314 mph) and French Bloch 151 (304 mph). On the other hand, some of the best American attack models--the XA-21 (257 mph), the A-20 (395 mph), and the A-20A (347 mph)--were as good as or ahead of such foreign models as the French Bloch 170/174 (323 mph), the Italian Ba-65 (267 mph), and the German Ju-87 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,[16] but trailed both the Italian Pi-108 (250 mph) and the German Ju-89 (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 materiel 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

---

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, 28 June 1939, in A. J. Lyon project record book No. 13. See also, for varying figures, the MD chart, "Characteristics and Performance of [Foreign] Airplanes," 15 Jan. 1938, in AAG 452.1 bulk files. Stirling and Manchester are not listed by the Kilner Board, but see ibid.

[redacted]

for installation in the XB-19 ordered in 1939; and 1,600 and 1,700 horsepower had been reached in the Wright R-2600-3 and -7, planned for use in the B-23, A-20A, and A-20. Take-off ratings between 1,000 and 1,200 horsepower, however, were the top limits of engines actually installed, in both developmental and standard airplanes, as of about September 1939. In most cases these ratings had already been achieved in 1937 or earlier:[17]

1,000 hp:	Pratt and Whitney R-1830-11, in XB-15 (1937) Wright R-1820-51 and -53, in B-18A (1937), YlB-17A (1939), and C-42 (1939), and planned for B-17B Allison V-1710-7, in XP-37 (1937)
1,050 hp:	Pratt and Whitney R-1830-13, in P-36A (1938) and XP-42 (1939)
1,060 hp:	Allison V-1710-19, in XP-40 (1939)
1,150 hp:	Allison V-1710-11, in XFM-1 (1937), YP-37 (1939), and XP-39 (1939), and similar engines (sub-models 27, 29, 37) planned for YP-38 and YP-39
1,200 hp:	Pratt and Whitney R-1830-13, -17, and -19, in C-41 (1938), P-36A and C (1938-39), YA-19 (1939), and XP-41 (1939), and similar engines (sub-models 33, 35) planned for XB-24 and YP-43 Pratt and Whitney R-2180-1, in XB-21 (1939)

These horsepower ratings did not represent the actual frontier of research in power plants in 1939, because there doubtless were under development improved models of these and other engines that were not yet ready for installation. Furthermore, this listing covered only the conventional internal-combustion engines. Jet propulsion, while no unit for aircraft use had as yet been achieved in the United States, had been studied as a university research project since December 1938, under an agreement between the Air Corps and the National Academy of Sciences.

---

17. MD chart, "Characteristics and Performance of U. S. Army Airplanes," 1 July 1939, Sheets A and B.

[redacted]

As to air ordnance, the maximum bomb weight of the advanced airplane models ranged as follows: 8,800 lbs., Y1B-17A; 12,000 lbs., XB-15; 9,040 lbs., XB-24; and 37,000 lbs., XB-19, the latter only in the contract stage and not to be completed until 1941, and then to be used only as a "flying laboratory." The maximum usable bomb size was only 2,000 lbs. for the medium and heavy bombers; 600 lbs. and 1,100 lbs. for the attack models; and 20 lbs. and 30 lbs. for those pursuits (XP-40 and P-35) that could be used as fighter bombers.[18] Airborne rockets were still in the future.

As to armament, most of the bombers in 1939 carried only .30-caliber guns, although the new Y1B-17A had fittings for five .50's, and three of the seven gun positions of the forthcoming XB-24 were for .50's. Fire control systems, however, were antiquated. In 1937 they had been regarded by the tactical units as "practically the same as [those of] at least ten years ago,"[19] and wholly unfitted for the defensive missions of the unescorted bomber, a tactical situation visualized as early as 1933. In September 1939 neither the B-23, the Y1B-17A, nor the forthcoming B-17B and XB-24 was equipped with turrets, while the B-18A had only a single .30-caliber turret on top.[20] Both in the Air Corps and among its industrial contractors turret development was seriously trailing England

---

18. Ibid.
19. "Notes on Air Corps-Ordnance Department Conference," 18 June 1937, quoted in draft ATSC historical study, "Power Turrets [1917-1944]," Chap. II, p. 4.
20. Ibid.; MD Field Service Section, "Armament and Field of Fire--Tactical and Training Airplanes [1938-1941]," [about 1941], in AAG 452.1, Bulk files (misfiled under 27 July 1938).

[redacted]

and Germany. Fighter armament, on the other hand, was perhaps not so critical, although the sizes and numbers of guns were limited. No pursuit plane in mid-1939 had more than 4 fixed wing guns, although planes with more had been experimentally tested 15 and 20 years earlier—the GAX with 8 guns in 1920 and other ground-strafing planes with 6 to 10 guns in 1925.[21] Two of the experimental pursuits (the XP-39 and the XFM-1) mounted one and two 37-mm cannon, respectively,[22] but the experimental use of this weapon was at least as old as the considerable tests of the cannon-mounted GAX in 1920 and subsequent years.[23]

Navigation and communications equipment in the advanced airplane models were limited in 1939 to the standard radio compass, the marker beacon receiver, and the command and liaison sets.[24] Airborne aids for all-weather navigation and target detection and tracking were non-existent; and development was lagging, whether because of the economy budget of the Signal Corps (the Army-wide procurement agency for radio and related equipment), the greater emphasis on ground-force communications, the existence of Air Corps apathy, or other reasons.[25] Economy

---

21. The Official Guide to the Army Air Forces (1944 ed.), pp. 346-47, 351.
22. MD chart, "Characteristics and Performance of U. S. Army Airplanes," 1 July 1939, Sheet A, tabulation showing armament and radio equipment for all developmental airplane models, attached to R&R, Supply Div. to Col. Carl Spaatz, Plans Sec., 9 Sep. 1939, in AAG 452.1, Airplanes, General.
23. The Official Guide to the Army Air Forces (1944 ed.), pp. 346-47.
24. Tabulation showing armament and radio equipment for all developmental airplane models, attached to R&R, Supply Div. to Col. Carl Spaatz, Plans Sec., 9 Sep. 1939, in AAG 452.1, Airplanes, General.
25. See draft AAF historical study, "The Development of Radio and Radar Equipment for Air Operations, 1939-1944."

[redacted]

and cost reduction had certainly been the limiting theme in 1938 in the deliberations of the Air Corps Technical Committee,[26] which allocated only $6,660 for "obstacle detection and collision prevention" research,[27] a field of research which later was to contain solutions for all-weather flying and bombing-through-overcast (BTO).[28] On the other hand, ground equipment for enemy aircraft warning did exist: the SCR-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.[29] In September the Air Board called for an "adequate" aircraft warning service,[30] and by December 1939 the Air Corps and the General Staff were planning a new Air Defense Command to employ detectors in a coastal warning service.[31]

The equipment for air defense was definitely inferior, however, to the best European devices, especially the British CH equipment (range 185 miles, showing both azimuth and altitude). Furthermore, the Air Corps

26. Lt. Col. Earl L. Naiden, GHQ Air Force, Chairman of ACTC Subcommittee on "item 9" (communications), and members representing the OCAC, the Signal Corps, and the Aircraft Radio Laboratory at Wright Field.
27. "Report . . ." of ACTC Subcommittee on "item 9" (communications), Dec. 1938, in AAG 334.8, bulk files.
28. BTO and target detection were not mentioned in the Air Corps Technical Committee report, but they were similar to "obstacle" detection and ultimately used some of the same solutions.
29. The SCR-268 was first demonstrated in May 1937, and the SCR-270 (two models), in November 1939. [Annual] Report of Chief Signal Officer, 1942, pp. 219-20, quoted in draft AAF historical study, "The Use of Radio and Radar Equipment by the AAF, 1939-1945," pp. 39-40, 51.
30. "Air Board Report," 15 Sep. 1939, Tab C, p. 3, AG 320.2. (6-26-39), in A. J. Lyon project record book No. 15-A, in Office of DAC/AS, M&S.
31. Col. Carl Spaatz, "Notebook" (Nov. 1939-March 1940), 27 Dec. 1939, meeting with "Gen. Strong's Office" (WDGS); and 12 Feb. 1940, assignment of Maj. G. P. Saville to Gen. Chaney's new Air Defense Command, in AAG bulk files.

[redacted]

was lacking the fundamentally related recognition devices (IFF). Not until Air Corps observers returned from England late in 1940[32] was America's inferior position to be fully appreciated in the Army[33] and energetic steps taken to embark on a comprehensive radar development program.

Compared with the critical status of air defense aids, the guided-missiles situation was not so serious or so urgent a problem in 1939. The idea of remote-controlled "aerial torpedoes" and pilotless airplanes was not new in 1939. Although there were no active developmental projects either in the Signal Corps or the Air Corps at the time, an aerial torpedo had been developed for the War Department by Charles F. Kettering in 1917. It had been mechanically rather than radio controlled, and was wholly lacking in precision even when it functioned. It had finally been abandoned by the Air Corps in 1935 because of insufficient funds,[34] and when the idea of a pre-set glide bomb was revived in World War II, the AAF regarded it wholly as a temporary substitute for a precision missile.[35] 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

---

32. The mission included Lt. Col. A. W. Marriner and others. After its report of about 1 December 1940, a "full-dress" meeting was held between the Air Corps, the Signal Corps, the Navy, and the new NDRC to discuss the comparative merits of British and American detection, recognition, interception, and other radar equipment. (See minutes of conference, 13 Dec. 1940, in AAG 676.3, Wireless--Radio System.)
33. Memo for Maj. Gen. H. H. Arnold, DC/S for Air, by Brig. Gen. G. H. Brett, "The Assistant," 13 Dec. 1940, in ibid.
34. Air Corps Board Report No. 9, 25 Oct. 1935, pp. 3-4, quoted in draft AAF historical study, "Radio and Radar Equipment for Air Operations, 1939-1944," p. 57.
35. Ibid.

[redacted]

use in the development of an aerial torpedo.[36] More practical, from the standpoint of economy and immediate tactical use, had been the related radio-controlled pilotless airplane for target use in gunnery training. The Army had completed its first successful test of such a target plane in 1934, when radio controls and Automatic Flight Control Equipment were sufficiently advanced to make the project workable.[37]

Military Requirements and Strategic Needs, 1933-1939

If the developmental models actually on hand in the Air Corps in 1939 did not measure up to foreign achievements, certainly the Air Corps in 1939 had a valuable inheritance of ideas and partially completed experiments from the years of peace between 1918 and 1939, covering the whole range of combat airplanes, power plants and propellers, ordnance and radio equipment, and guided missiles. Furthermore, its strategic needs were being carefully formulated.

In terms of strategic and tactical needs, the Drum Board's "air plan for the defense of the United States" of 1933[38] was still valid, so far as the areas of operation were concerned. This Board had visualized the Army air arm as serving in its customary roles of bombardment, pursuit, transport, and reconnaissance, all toward the goals of achieving air supremacy, lending ground support, and engaging in offensive land-based air operations over land and/or sea areas with or

---

36. Materiel Division, Annual Report, Fiscal Year 1930, p. 51.
37. Draft AAF historical study, "Radio and Radar Equipment for Air Operations, 1939-1944," Chap. V.
38. "Report of Special Committee, General Council, on Employment of Army Air Corps under Certain Strategic Plans," approved 11 Oct. 1933, in AAG 334.7, bulk files.

[redacted]

without sea forces; and making full use of long-range reconnaissance, "demolition" of the enemy's interior installations, and "interdiction" of enemy movements. Its operational theaters were to be seven "critical areas" surrounding the United States and its outlying bases in the Western Hemisphere, and five areas corresponding to the overseas possessions of the United States. The war plans used by the Drum Board were the "Red" (British Empire), the "Orange" (Japanese Empire), and the "Red-Orange" plan, which assumed "a coalition . . . with Japan."[39] In the latter plan, considered the most likely, Japan would merely be "contained," while "full power" was exerted against "Red." The Soviet Union and China were regarded as either neutral or friendly to the United States, while Germany (in the first year of Nazi control) and Italy (still unprovocative in 1933) were ignored entirely. This political and strategic situation was the one in which the designs of the two new heavy bombers were undertaken for the Air Corps by Boeing--the "Project 299" airplane (which became the XB-17 in 1935) and the XB-15 long-range bomber (to be delivered in 1937).[40] By 1939 the seven strategic areas of 1933 were still valid, and were re-expressed by the Air Board in September 1939.[41] The potential enemy, however, had shifted violently

---

39. The latter wording is quoted from memorandum by C/AC on "Air plan . . .," 27 July 1933, which was Exhibit I in the Drum Board report; but the Board echoed much the same opinion in its own report.
40. Another interpretation, that the XB-17 was designed instead for a Pacific war, with Japan a more likely enemy than Germany "in 1935," is given in another AFSHO special study, "Review of Aerial Warfare for the Scientific Advisory Board [Group]," p. 6.
41. The Air Board was appointed 23 March 1939, and its report approved by The Adjutant General (that is, the General Staff and the Secretary of War) on 15 September 1939. See its report, AG 320.2 (6-26-39), 15 Sep. 1939, p. 1, in A. J. Lyon project record book No. 15-A, in Office of DAC/AS, M&S.

[redacted]

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, and were so restated in September 1939. The Air Board, in its report on strategic and tactical requirements made to the General Staff, reiterated the "defense" missions 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 five-year program for research and development for the Air Corps.[42] The new political situation was too obvious to mention in the Board's directive. Instead, the immediate problem of military requirements, as posed in General Arnold's directive, was to prepare a program for catching up with the admittedly superior foreign progress.[43] Its report of recommendations,[44] 28 June 1939, represented the views of OCAC, of the tactical air arm, and of the

---

42. "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.
43. Memo for President, Research Board (Brig. Gen. W. G. Kilner), by Maj. Gen. H. H. Arnold, C/AC, 10 May 1939, in ibid., Exhibit A.
44. Made by Brig. Gen. W. G. Kilner, AC, and Col. Charles A. Lindbergh, AC Reserve, both attached to OCAC; Lt. Col. Carl Spaatz, Plans Sec., OCAC; Lt. Col. Earl L. Naiden, GHQ Air Force; and Maj. A. J. Lyon, Materiel Div., Wright Field.

[redacted]

materiel center, and consisted of a comprehensive set of proposed military characteristics for combat airplanes, related weapons and equipment, and trainer and ground-arm 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 labeled as general military objectives that would involve "a compromise between requirements for military use and technical features of design." Such compromises properly could "only be determined during design and construction by engineering calculations, and wind tunnel and flight tests." To substitute preconceived, detailed characteristics for broad objectives would "restrict the technical staffs at Wright Field and the aircraft manufacturers in determining the compromise of technical features . . . [for] the best airplane for military use." Manufacturers working on experimental contracts must be given "wide latitude in the application of their ingenuity in meeting technical requirements of the Air Corps."[45]

Among the advanced ideas brewing in the Air Corps in 1939, the following could be translated into combat materiel[46] in five years or

---

45. Kilner Board, Report, especially pp. 5, 9-10, 13-14, in A. J. Lyon project record book No. 13.
46. Types other than Air Corps combat, for which military characteristics were submitted: corps and division observation; reconnaissance and photographic; primary, basic, and advanced trainer; and transport. See Kilner Board, Report, Tabs G through O, in A. J. Lyon project record book No. 13.

[redacted]

less, in the view of the Board:

Long-range bomber, achievable in 5 years: 8,000-mile range (3,000-mile radius); 400 mph; 200,000 lbs.; normal bomb load, 4,000 lbs.; dependent on development of 3,000 hp engines.

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

Medium bomber, 2-engine: 2,667-mile range (1,000-mile radius); 400 mph; 30,000 lbs.; normal bomb load, 500 lbs.

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; 800-mile range (300-mile radius).

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

Engines: 1,800-2,400 hp and 3,000-hp engines, for fighters and long-range bombers, achievable by 1941; given earliest 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 five-year program were jet propulsion, guided missiles, and radio aids. The limited jet research project with the National Academy of Sciences was only just getting under way, and apparently its practical future for 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 basic research . . ., aerial targets, aerial torpedo,

[redacted]

etc.," [47] but the Kilner Board 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-and-night operation . . . under all flying weather conditions." But all-weather aids, detectors, and target trackers under development by the Signal Corps were all excluded, presumably because the Board was concerned only with materiel under Air Corps procurement "cognizance" and not with the research programs of the Signal Corps, or, for that matter, with the programs of the other supply services of the Army such as the Ordnance Department, the Chemical Warfare Service, the Corps of Engineers, and the Quartermaster Corps.

By September 1939 the Kilner Board program had been revised downward, in connection with the immediate budget problem for the fiscal year 1941.[48] The 8,000-mile long-range bomber had been deleted (but was to be revived later in the XB-35 and the XB-36), but the 5,333-mile bomber survived, as well as the other bombers, the pursuits, and the engine and fire control projects.[49] The Air Board, which had made these revisions, went beyond the Kilner Board to emphasize that aircraft development "must be

---

47. Staff study by Materiel Div., n.d., p. 6, in Kilner Board Report, Appendix I, in A. J. Lyon project record book No. 13.
48. Mentioned in memo for Materiel Div. by C/AC, 29 Aug. 1939, in A. J. Lyon project record book No. 13.
49. WD, "Research and Development Program, Fiscal Year 1941," Table I for Air Corps (rev. 7 Sep. 1939, blueprint copy); and AG 111 (3-30-39), 10 Aug. 1939 (copy), both in ibid. See also "Air Board Report" (15 Sep. 1939, Tab F, p. 4, in A. J. Lyon project book No. 15-A), which, with WDGS and S/W approval, concurred in the need for a 5,333-mile bomber (2,000-mile radius) for use in Atlantic and Pacific areas.

[redacted]

paralleled in the field of accessories, particularly armament and communications equipment, and that this latter development must be synchronized with the development of the airplane itself."[50]

The Air Corps Experimental Establishment, 1919-1939

The laboratories, special hangars, and other experimental facilities at Wright Field in 1939 comprised a plant, valued at about $10,000,000, which had been under development since before March 1927, when the Materiel Division was transferred to that location from near-by McCook Field, also at Dayton, Ohio. The experimental facilities were divided largely into laboratory branches, corresponding to each of the large categories of air materiel: Aircraft, Power Plant, Propeller, Armament, Photographic, Equipment, Materials, Aero-Medical, and Radio, the latter a Signal Corps rather than an Air Corps installation at Wright Field. A substantial portion of each year's budget had been used for the continuous improvement of the Field. Thus, in the fiscal year beginning 1 July 1939, $544,343 was spent for machinery and laboratory apparatus, and $199,331 for general maintenance and improvement;[51] and $6,481,000 was earmarked for the construction of additional laboratories and other fixed equipment.[52] The Air Corps was skillful in impressing public

---

50. "Air Board Report," 15 Sep. 1939, Tab G, p. 1, in A. J. Lyon project book No. 15-A. This recommendation on electronics was ultimately approved, in terms of Signal Corps--Air Corps Administrative reorganization, in the DC/S directive of 26 August 1944, which transferred jurisdiction over air communications equipment from the Signal Corps to the AAF.
51. MM&D, "AAF Research and Development Program" [about April 1944], in M&S Development Engineering Branch file, 700.430 Kilgore Committee--Office of Tecnological Mobilization.
52. Air Corps section of WD, "Research and Development Program, Fiscal Year 1940," 23 May 1939, in AAG 400.112, Test, Development Work.

[redacted]

opinion with its "aeronautical research center" at Wright Field,[53] 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 aircraft engine. Among other equipment were engine test stands, static test equipment, a 40,000-foot altitude pressure tank, and a high-altitude plane (the XC-35) pressurized at 35,000 feet.[54] These were only a few of the 50 or more groups of specialized testing equipment on hand in 1939.[55]

As to the research and testing staff at Wright Field, figures segregated according to research, production, and other materiel 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 nonprofessional

---

53. Before the war the Air Corps had opened many areas of Wright Field to the visiting public, including a historical museum set up primarily for public education. See AR 95-40, "Army Aeronautical Museum," 11 June 1942 and earlier eds.
54. Science News Letter, 8 July 1939, pp. 26-28. This article is only one of hundreds published in popular magazines during these years. No attempt is made in this historical study at a critical appraisal of the Materiel Division's public relations policy, an important element in stimulating popular appreciation for military research.
55. A convenient listing of Wright Field's equipment (as of 1935, a few years earlier), is found in the Directory of Inspection Services and Testing Laboratories of the Federal Government (published by the Treasury Procurement Div. and the National Bureau of Standards, 1935), pp. 183-85; copy in NBS Library. The superseding edition (1944, same title) excludes Wright Field, as well as the NACA, while at the same time listing the Navy Bureau of Aeronautics laboratories at Philadelphia.

[redacted]

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,[56] a personnel situation that had its origins at McCook Field in 1917. Wright Field was consequently a "civilian" military post, and its long experience with the use of civilian experts in technical phases of military administration was unique in the armed services. Perhaps historically this was just as significant as the later, more widely publicized appearance of civilians in the strategic and tactical councils of the Army in World War II.[57] It was a common observation within the Air Corps that "the [Materiel] Division is run by a lot of civilians."[58]

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

---

56. 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.
57. 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.
58. Capt. C. S. Irvine, "Special Personnel Study on Civilian Personnel of the Materiel Division . . .," 22 Jan. 1939, p. 12, in AAG 321.1, bulk files. In another connection, General 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 Sep. 1939, in AAG 321.9, Materiel Div.)

[redacted]

Aeronautics, composed largely of officers.[59] Not that the personnel situation was in perfect condition in 1939. Insufficiency in numbers was an obvious problem, and the Chief of the Air Corps in May 1939 had asked the Kilner Board to recommend 800 more civilians for research and development work.[60]

Other more serious problems than numbers existed. A Wright Field survey in January 1939[61] had urged that its experimental personnel must constitute "a cross section of Air Corps officer personnel and civilian engineers, clerks, mechanics, and laborers, such as will be found in industry," and the leadership must be adequate to insure proper coordination with industry and with the tactical organizations, and to avoid dangerous errors in engineering decisions. The objective should be "a permanent Works Laboratory" available for research and development, as well as for production liaison and testing for the Materiel Division and industry, and service engineering tests for the Air Corps.[62] Salaries must be higher, in order to recruit and hold 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."[63]

---

59. Opinion of the Federal Aviation Commission (Howell Commission), in its Report, pp. 154-55.
60. Memo for C/AC, n.d., in Kilner Board report, 28 June 1939, Appendix 1, in A. J. Lyon project record book No. 13. The Board made no recommendation, but under the new appropriation for 1939-1940 this civilian strength was virtually reached--an increase from 1,759 to 2,478 civilians. See Materiel Command Historical Office, "History of the Materiel Command, 1926-1941," p. 6a.
61. Capt. C. S. Irvine, "Special Personnel Study on Civilian Personnel of the Materiel Division," 22 Jan. 1939, in AAG 321.1, bulk files.
62. Ibid., p. 15.
63. Ibid., p. 12.

[redacted]

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 permanent engineers."[64]

Engineering officers, compared to the civilians, were regarded as inferior in numbers and training in 1939, the survey had found.[65] For example, there were only one pursuit and one bombardment project officer, each with one civilian assistant; and each team handled three or four projects, making it impossible to conduct adequate visits to the plants and adequate operations and planning at the field.[66] Again, a permanent nucleus of officers was indicated—a program that also earlier had the support of the Howell Commission.[67]

---

64. Ibid., p. 13.
65. In addition, after the Chief of the Materiel Division and his immediate staff were moved to Washington in October 1939, the shortage of experienced engineering personnel applied to Washington as well. General Brett complained that "Whenever a special development or research project comes up such as . . . the leak-proof tank, . . . fire control, redesign of equipment for speed performance, etc., officers have to be taken from other important work to be concentrated upon these developments." An immediate remedy, he suggested, was to withdraw the 15 Wright Field officers at the Air Corps Tactical School at Maxwell Field, and discontinue the school entirely. (R&R, Brett to C/AC, 13 May 1940, in AAG 321.9, Materiel Div.)
66. Irvine, "Special Personnel Study on Civilian Personnel of the Materiel Division," 22 Jan. 1939, pp. 9, 11-12, in AAG 321.1, bulk files.
67. See its Report, pp. 154-55. Both officers and civilians were included in the Commission's idea of a "Corps of Aeronautical Engineers."

[redacted]

As to officer training, the survey in January 1939 had recommended a doubling of the enrollment at the Air Corps Engineering School at Wright Field,[68] and a triple increase in the assignment of officers as postgraduate students in university engineering departments.[69] Advanced university training for engineering officers had until recently been virtually nonexistent for years, nor had a program been recommended by the Howell Commission in 1935.[70] The War Department had authority enough--more than that of any other federal agency[71]--to expand this training program, including enabling legislation dating back to 1916 that permitted up to 2 per cent of the officers of the Regular Army to be detailed to such institutions.[72] The Air Corps, furthermore, had been given special authorizations, including an act of May 1920 permitting as many as 25 officers to be trained in aeronautical engineering at a time, and an

---

68. The Air Corps Engineering School was the Army's center for the training of Air Corps officers primarily for materiel development and production. One other Army school devoted to materiel matters, the Army Industrial College established about 1920, was interested primarily in industrial planning, production, and contracts on an Army-wide scale.
69. Irvine, "Special Personnel Study on Civilian Personnel of the Materiel Division," 22 Jan. 1939, pp. 4, 12, in AAG 321.1, bulk files.
70. The Federal Aviation Commission (Howell Commission), while it spoke broadly in favor of a "corps of aeronautical engineers," made no recommendation for postgraduate training in civilian schools. This omission is especially significant in view of the Commission's membership, which included Jerome C. Hunsaker, then head of the M.I.T. mechanical engineering department.
71. Since 1926 no federal agency except the War Department (whose legislative authority is cited below) had been permitted by the Comptroller General to send government employees to technical and other civilian educational institutions. See the latter's ruling of 9 July 1926, copied in National Resources Committee, Relation of the Federal Government to Research (1939), p. 37.
72. Acts of 30 June 1916, 39 Stat. 166; 4 June 1920, 41 Stat. 786; amendment of 8 June 1926, 44 Stat. 705; all contained in 10 U. S. Code 535. See also later, broader amendments, 13 May 1941 (55 Stat. 189) and 30 June 1941 (55 Stat. 369), in ibid. An act of 6 February 1942 (56 Stat. 50) removed any percentage limitations on any branch of the Army and on any of the personnel categories--Regular Army, Army of the United States, and enlisted men.

[redacted]

all-inclusive provision in the Air Corps expansion act of 3 April 1939, permitting postgraduate training "without reference to any [earlier statutory] limitation."[73] In terms of actual enrollment, Wright Field had sent three officers to Michigan, California Institute of Technology, and Stanford, in September 1938 to study aeronautical engineering, and four officers to California Institute of Technology, Stanford, and Massachusetts Institute of Technology in September 1939[74]--one more but hardly the triple increase recommended by the survey earlier in the year. In both of these enrollments, Wright Field and Office of Chief of Air Corps headquarters were apparently operating under the 2 per cent rule rather than under the broader legislation of May 1920 and April 1939.[75] 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

---

73. Act of 10 May 1920, 41 Stat. 594, in 10 U. S. Code 298; and act of 3 April 1939, 53 Stat. 556, sec. 2.
74. Memo for TAG by C/AC, 1 March 1938; and teletype, Exec., MD to Personnel Div., OCAC, 9 May 1939, both in AAG 210.66, Detail to Civilian Educational Institutions. Meanwhile, officers from elsewhere in the Air Corps were taking some advanced university work: 1 in 1937, 15 in 1938, and 4 in 1939, all in meteorology at C.I.T.; and 3 in 1939 in mathematics, at M.I.T.
75. As late as April 1940, the OCAC Personnel Div. was still invoking the 2 per cent rule. (See R&R, Personnel Div. to MD, 12 April 1940, in AAG 210.66, Detail to Civilian Educational Institutions. The 1939 enrollment was 2.7 per cent of Wright Field's officer strength of 149 (as of 1 July 1939). The statutes of 1916, 1920, and 1926 (cited above) did not, however, restrict an individual post of 2 per cent. Rather, the quota applied to each Army branch (e.g., Air Corps) as a whole.

[redacted]

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[76] or of accomplishment in terms of new and better airplanes and weapons, they were the indispensable 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.[77] The funds specifically earmarked for "research and development" are shown in the table on the following page. These annual sums are in general a conservative understatement of

---

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

77. For example, the Air Corps research budget in 1937 was $4,518,460 (see tabulation on p. 49), 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 (1935-1936 estimate); and all endowed foundations, $3,000,000 (estimated annual average, 1919-1938). (See National Resources Committee, Relation of the Federal Government to Research, pp. 3, 8, 65, 67, 180).

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 Aeronautics	4.1	5.1
National Bureau of Standards	1.4	1.5
National Advisory Committee for Aeronautics	1.9	2.0

[redacted]

[redacted]

Air Corps Appropriations for Experimentation, Research, and Development, 1920-1940[a]

Fiscal year	"Research and Development"[b]	Civilian pay roll[c]	"Service Test"[d]	Total research appropriation
1920				$ 4,522,078
1921				5,928,062
1922				4,175,545
1923				3,150,517
1924	$1,180,000	$1,820,000		3,000,000
1925	1,190,000	1,890,898		3,080,898
1926	900,000	1,730,000		2,630,000
1927	702,720	1,481,280		2,184,000
1928	750,000	1,450,000		2,200,000
1929	694,550	1,569,090		2,263,640
1930	675,930	1,580,000		2,255,930
1931	675,930	1,623,331		2,299,261
1932	644,599	1,648,288		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	1,561,815	310,000	3,796,799
1936	3,968,563	1,648,288	350,000	5,966,851
1937	2,468,900	1,657,060	392,500	4,518,460
1938	2,928,135	1,104,950	316,805	4,349,890
1939	2,043,409	1,201,550	329,331	3,574,290
1940	8,037,962	1,588,838	233,200	10,000,000

---

a. Adapted from work sheets and tabulations in M&S, including: teletype, Wright Fld. to AC/S (E), Hq., MC [about 6 Feb. 1943]; and data from Baker Board, Report, 1934, all filed in M&S 700.430 Kilgore Committee--Office of Technological Mobilization.

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

c. Known also as "Project 72."

d. Known also as "Project 73."

[redacted]

money actually spent by the Air Corps for research, because they did not include such considerable items as the military pay for the engineering officers at Wright Field, the expenditures for construction of laboratory and other specialized facilities,[78] and other items that for budgetary and accounting purposes could not be labeled "Research and Development."[79]

Substantial as these research budgets were up to 1940, there had been from year to year a striking disparity between their very slow growth (if not retrogression) and the relatively rapid increases for the Air Corps as a whole. While the research budget eventually rose from 2.6 millions in 1926 to 3.5 millions in 1939, the entire Air Corps budget mounted from 16 to 73 millions.[80] Historically compared, from 1920 to 1940 the research budgets showed still other trends: that the research budgets of the immediate postwar years of 1920, 1921, and 1922 were substantial; that they were not matched by comparably high budgets until 1936; and that during the intervening meager years 1923-1935,

---

78. For example, the fiscal year 1940 budget included, in addition to projects 71, 72, and 73 (all for research and development, civilian pay roll, and service test equipment), also $6,481,000 for project 75, "Additions to Laboratories, and Equipment." See Air Corps section of "War Department Research and Development Program, Fiscal Year 1940," 23 May 1939, in AAG 400.112, Test, Development Work.
79. The research budgets of the Air Corps, the other Army supply services, and the Navy supply bureaus all are commonly an underestimate of funds actually spent, because of factors such as the above, rather than because of any conscious "hiding" of the function of research under other more innocuous headings. Civilian federal agencies, on the other hand, had tended to hide some of their research funds under other headings as "window dressing," in order to avoid the popular stigma attached to federal research activities. See National Resources Committee, Relation of the Federal Government to Research, pp. 63, 87-88.
80. See tabulation of Air Corps appropriations, 1926-1939, in AAF Historical Studies: No. 22, Legislation Relating to the AAF Materiel Program, 1939-1944, p. 161.

[redacted]

appropriations reached their lowest figure in 1927, ironically near the peak of America's financial expansion of that decade, rather than during the depression years 1931-1935. 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.

To evaluate in this manner a 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 Bureau of the Budget or the War Department) regularly cut the Air Corps budget estimates during these years.[81] 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 AAF. It was during the intervening years of peace and "normalcy" that 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 with the White House, the Budget Bureau, the War Department, the Congress, an apathetic or hostile public opinion, or an ineffective public relations policy by the Air Corps and the War Department, the inadequate budgets were the final, immediate explanation why the Air Corps

---

81. The fallacy of this legend is discussed in ibid., pp. 56-57.

[redacted]

could not explore (or subsidize) the numerous, tantalizing avenues of pure and applied science that had "possibilities" for new air weapons.

Superimposed on Wright Field's resources for research and development was an administrative and military hierarchy which controlled and supervised expenditures; assigned experimental and test projects and their priorities; formulated policy with respect to cooperative research in industry, the universities, and the other military and federal laboratories; and sat on evaluation boards and other committees when the new airplane, weapon, or design was being appraised. The authority for these responsibilities over materiel development was derived not only from the Air Corps act of 1926[82] and subsequent Army Regulations,[83] 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.[84] 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.

---

82. For a history of the act of 2 July 1926 and other legislation governing the organization of the military air arm, see AAF Historical Studies: No. 25, Organization of Military Aeronautics, 1907-1935.

83. 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 Materiel 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).

84. The National Resources Committee in 1937-1938, surveying the nation's scientific resources (Relation of the Federal Government to Research, pp. 25-27) called attention to this fact.

[redacted]

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 Harley M. 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 or not 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.

Immediately supervising the nine laboratory branches at Wright Field in 1939 was the Chief of the Experimental Engineering Section, Maj. 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.[85]

---

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

[redacted]

One major change did occur in 1939, however, which represented 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.[86] Ever since 1926 Wright Field had 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.[87] It had had no rank or prestige comparable to the other basic Air Corps offices for training, personnel, and operations, and it had been abolished about September 1938. Now in October 1939, after some opposition in Washington,[88] the Chief

---

86. Materiel Div., L. I. No. 1, 2 Oct. 1939; copy in Materiel Command Historical Office, "History of the Materiel Command, 1926-1941," pp. 38b-38c. The move was announced by a press release in September 1939.

87. This section, established 14 October 1926 with one major, three captains, and four professional civilians, was at first called "an activity of the Materiel Division." Before that time, the Engineering Division (1917-1926) off-and-on had had a single representative in Washington--Capt. R. L. Walsh in 1926. Memo for Exec., OCAC by Maj. L. W. McIntosh, Chief, Materiel Liaison Sec., 25 May 1927, in AAG 321.9, Materiel Div.; and memo, 27 Jan. 1926, in AAG 400.112, Tests and Experiments, WF.

88. The Supply Division had opposed, while Plans and others favored the move. See AAF Historical Studies: No. 10, Organization of the Army Air Arm, 1935-1943, pp. 75-76. The move apparently also had General Arnold's support. General 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 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'." (Memo for C/AC by Brig. Gen. G. H. Brett, 13 Sep. 1939, in AAG 321.9, Materiel Div.)

[redacted]

of the Materiel Division moved to Washington, together with a small staff of planning officers including Maj. A. J. Lyon, Capt. B. W. Chidlaw, and Capt. J. F. Phillips (Maj. B. E. Meyers came to Washington later); and left his Assistant Chief, the Technical Executive, and the bulk of the technical and laboratory staffs at Wright Field. This Washington-Wright Field relationship was to continue virtually uninterrupted through the whole course of World War II, with almost no major organizational changes affecting research and development except changes in name, as shown in the table on the following page.

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 October 1939. The later, widely publicized decentralizations that were to accompany the general AAF reorganizations of 20 June 1941, 9 March 1942, and 29 March 1943 had only a slight effect on research and development policy and control. Wright Field activities continued, whether 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 merely underwent various changes in name, with, however, essentially the same leadership, the same nucleus of key officers and civilians, and the same channels over the whole period 1939-1945.[89]

Such a schematization of the history of the Air Corps research and development organization (as above) is of course a complete

---

89. Later, especially in 1944 and 1945, as the war progressed, more and more staff officers in Washington were assigned to overseas duty, such as Chidlaw in 1944, but many of the key personnel in AC/AS, M&S remained.

[redacted]

ORGANIZATION FOR RESEARCH AND DEVELOPMENT, 1926-1944

Date	Washington	Wright Field
Oct 1926	Materiel Liaison Sec of Supply Division	Materiel Div (MD), including Experimental Eng Sec (EES), with 6 type brs or labs
May 1937-Mar 1939	Same, until Sep 1938, when Section was abolished	Same, except development and production secs combined into a single Eng Sec
Apr-Sep 1939		Same, except Experimental Eng Sec restored, and Technical Staff and 2 additional labs estbd
2 Oct 1939	Chief, Materiel Div, moved here, including a staff section for Experimental Eng	Asst Chief, Materiel Div, including Technical Staff, Experimental Eng Sec, and 9 type labs
Dec 1941	Chief also dsgd as Asst for Procurement Services	Same, except Technical Staff placed within EES
9 Mar 1942	Redsgd CG, Materiel Command, including a Chief of Staff Experimental (C/S-E)	Same, except Materiel Div redsgd Materiel Center
29 Mar 1943	Redsgd AC/AS Materiel, Maintenance and Distribution, including Materiel Div, Development Eng Br	Redsgd Materiel Command, including Eng Div
17 July 1944	Same	Materiel Command, including Eng Div, placed under a new Director of Materiel and Services
19 July 1944	Redsgd AC/AS, Materiel and Services, including Materiel Div	Same
31 Aug 1944	Same	Materiel Command, including Eng and Procurement Div, and labs reorganized under 5 brs, made part of a new Air Technical Service Command
Nov 1944	Same, except Materiel Div, including Eng Br, and Research Liaison Br	Same

[redacted]

oversimplification if viewed as anything but a historical directory for convenience of reference. Not only were there occasionally lesser (but more subtle if not more significant) internal administrative changes not shown above, such as the establishment of a liaison office at the NACA in 1939; there were also minor internal reorganizations that were never announced and reorganizations that were announced but never put into effect. More fundamental was the fact that frequently the directives that led to them were based not on theories of management or even on good historical precedent, but on changes in research and development policies, especially policies as to military and strategic requirements, testing and proving procedures, industrial and university research projects, relations with other federal research agencies, and exchange of technical information with the Allies. It is sufficient here to outline some of the other agencies that existed in 1939 within the Air Corps and the War Department with staff functions that bore on research and development policy. Wright Field and the Materiel Division alone did not control policy. For example, the Field's representative on the Kilner Board in May-June 1939 (Maj. A. J. Lyon) had been the lowest ranking officer on the Board. Other War Department policy agencies were the following listed in general according to echelon:

Secretary of War
  AS/W (when contracts were involved)

General Staff
  Chief and Deputy Chief of Staff
  AC/S, G-4 (withdrawn from chain of command about 1941)
  Budget Division (when research budgets were involved)

Air Corps Technical Committee (usually representing OCAC, GHQAF, and WDGS; the Materiel Division supplied the Recorder after September 1939)

[redacted]

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)

Ordnance Department
Chemical Warfare Service
Signal Corps
Quartermaster Corps
Corps of Engineers
} and their respective inter-service "technical committees" on military requirements and military characteristics, each concerned with a category of materiel peculiar to air operations or common to all the combat arms.

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

The Scientific Potential for Air Supremacy, 1939

In Wright Field's analysis of the unsolved scientific problems confronting the Air Corps in 1939 was a basic, confident premise that America possessed a technical capacity which could, if properly mobilized, insure American air supremacy. Its fundamental recommendation was an administrative one: "the cooperative participation of the Air Corps,

[redacted]

the Navy, the N.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."[90]

Wright Field's confidence in America's aeronautical ability was matched by a widespread public confidence in America's general scientific prowess. For two decades of peace, science had been popularly regarded as an open sesame to prosperity and profit. This attitude had become an easy confidence, almost a worship of science. For example, advertising of newly developed commercial products in popular magazines frequently pictured, in full color, the stereotyped laboratory of test tubes, Bunsen burners, and bespectacled and 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 that of the British, who were more reticent if not apologetic in their publicizing of commercial products born of scientific research.[91] 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 deplored

---

90. ESMR No. 50-461-351, 18 Aug. 1939, "Future Aeronautical Research and Developmental Problems," prepared by E. Kotcher, Technical Staff, in M&S file on "F.Y. 1941 R&D Program."
91. See Bernal, The Social Function of Science.

[redacted]

the stories that the laboratory was being "prostituted" to war and that science would make war even more "horrible," and Nazi Germany was usually cited as the worst example of the use of science for anti-social goals.[92]

Symptomatic of this confidence in peacetime science, coupled with an apathy if not hostility to war research, was the survey of America's scientific resources in 1937-1940 by the National Resources Committee. Its directives in 1937 and 1938 and its recommendations in 1938 and 1940, respectively, were all stated in terms of national prosperity, national welfare, and the improvement of standards of living, all without specific reference to the war potential existing in America's laboratories.[93] Scientists had, of course, come a long way even to support social objectives such as the "national welfare." If they were shortsighted in 1939 about the importance of science in war, they probably merely reflected a common complacency in America and the other democratic nations, or the common political tactic that "war" and "defense" were subjects too indelicate to be mentioned to Americans.

A vast scientific potential did exist in America in 1939, regardless of whether it was useful for humanitarian purposes, for greater profit in business and industry, or for better weapons of war. America on the

---

92. Science News Letter, 1939, passim; Bernal, The Social Function of Science.

93. National Resources Committee, Research--A National Resource: I. Relation of the Federal Government to Research (1938); II. Industrial Research (1941). The second volume was published by the National Resources Planning Board, successor to the Resources Committee. In fairness to the committee, it should be noted that significant studies on phases of national defense research were actually included in both reports. In April 1941 the National Resources Planning Board, endorsing Volume II, added what sounds like an afterthought, that industrial research has "great importance in relation to both the present defense effort and also to developments in the postdefense period" (p. iii).

[redacted]

eve of the European war was spending over one half of 1 per cent of its total national income in industrial, university, and government laboratories, a proportion greater than that of Great Britain or Germany and exceeded elsewhere in the world only by the Soviet Union.[94] Within America's economic framework, the annual expenditures for research in the physical and natural sciences were estimated somewhat as follows:[95]

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

Furthermore, it was estimated that of these research expenditures, 25 per cent was being expended by these groups for work of potential military value even in the peaceful year 1938.[96] The scientific potential for war existing in 1939 in these institutions--governmental, industrial, and academic--will be estimated below, together with an appraisal of the extent to which the Air Corps could and did utilize these national resources for improving its weapons for war.

---

94. Estimates by Bernal, British physicist, in The Social Function of Science, pp. 64-65.

95. National Resources Committee, Relation of the Federal Government to Research, pp. 3, 177, 180. These figures, generally as of 1937, should be further qualified in that a given sum may sometimes be represented under more than one heading, e.g., Air Corps funds transferred by contract to a manufacturer for an aircraft design. The estimate for endowed foundations is a rough annual average based on total estimated foundation expenditures ($55,000,000) for the years 1918-1937.

96. E. V. Hollis, Philanthropic Foundations and Higher Education (1938), pp. 293-94, quotes this guess, applicable both to the United States and Great Britain: 25 per cent, military research; 50 per cent, industrial and related "pure" physics and chemistry; and 25 per cent, "agriculture and its supporting sciences." These categories are, however, hardly mutually exclusive.

[redacted]

Government Resources for Research by 1939

By 1939 federal agencies were exercising perhaps a greater influence and importance in the field of aeronautical science than in any other area of science. Far from taking second place either to industry-sponsored or to academically inspired research, the work of government laboratories and the existence of government controls were the primary impulse for the advancement of the art in the United States.[97] The federal government had a "paramount interest" in aeronautics stemming from the following three elements: (1) the Civil Aeronautics Authority and its predecessor agencies in the Commerce Department, which, as the regulatory body for civil aviation, controlled air worthiness requirements of commercial planes (that is, landing and take-off performance, airplane controls, and stability) by means of technical inspection and licenses; (2) the Air Corps itself (described earlier) and the Navy's Bureau of Aeronautics, both of which, as purchasers of airplanes especially during the formative years of the aircraft industry, had "set the trend of design by their specifications to bidders," reflecting requirements which normally were "set somewhat ahead of the existing state of the art, . . . based on the tactical needs of the services"; and (3) the National Advisory Committee for Aeronautics and its laboratories and facilities, through which the government provided basic, indispensable scientific knowledge on aeronautical problems common to commercial and military airplanes, in effect a substantial subsidy for basic aeronautical research, whether for peacetime or wartime use.

---

97. Views of Jerome C. Hunsaker, M.I.T., and a member of the NACA, in his nation-wide appraisal of aeronautical research resources, 1940, in National Resources Planning Board, . . . II. Industrial Research, pp. 127-43.

[redacted]

The NACA has been broadly publicized,[98] at least as well publicized as Wright Field,[99] 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 activity—"scientific research on the fundamental problems of flight"—stemmed from its original congressional mandate in 1915.[100] Its activities had never been merely "advisory," as its name implied, and by 1939 it had had a long history of actual research activities on many problems of aerodynamics, structures, propulsion, and materials.[101]

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

In 1939, NACA appropriations for research, laboratory construction at Langley Field, and other activities totaled $4,063,980, of which

---

98. For example, see survey by Hunsaker, in ibid., pp. 134-36; NACA Annual Reports, 1916 to date; confidential minutes of NACA Executive Committee, disseminated to the AAF and elsewhere; and NACA references in New York Times Index, Industrial Arts Index, and other indexes to popular and technical publications.
99. The NACA apparently is subsidizing the preparation of an official history by George W. Gray, to be released to the general public; Wright Field's history is primarily for administrative reference use.
100. Naval Appropriation Act of 3 March 1915, 38 Stat. 930. For amendments and related legislation, see 50 U. S. Code 151, 152, 153.
101. Survey by J. C. Hunsaker, in National Resources Planning Board, . . . II. Industrial Research, p. 136.

[redacted]

$1,708,430 had been obligated during the fiscal year.[102] These sums corresponded with expenditures in previous years as follows:[103]

Expenditures of the NACA, 1919-1939

Fiscal Year	Total Expenditures	Pay Roll and Other Personal 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	193,859	101,696	15,228
1923	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	62,763
1928	529,144	387,372	51,493
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	600,043	99,428
1934	690,240	581,846	28,264
1935	747,827	616,208	33,914
1936	1,157,746	775,114	177,751
1937	2,337,638	928,337	1,200,252
1938	1,918,868	987,571	660,636
1939	1,708,430	1,065,812	398,266

In facilities, the NACA in 1939 had a modest staff of 575 engineers, technical assistants, and other employees,[104] most of whom were located at its Langley Memorial Aeronautical Laboratory, on a site at Langley

---

102. Regular 1939 appropriation (23 May 1938), $1,700,000, plus Supplemental (2 May 1939), $2,363,980, totaled $4,063,980. The large unexpended balance was carried over to the next year (with congressional approval), chiefly for construction of additional facilities at Langley Field. (NACA, Annual Report, 1939, p. 46.)

103. 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.

104. Fifty-four of them were in Washington. Figures from NACA Personnel Office.

[redacted]

Field given to the NACA in World War I by the War Department.[105] Its buildings and equipment, which were more impressive, included the following:[106]

8-foot, 500-mph wind tunnel for testing scale models
60 x 30-foot wind tunnel for testing full-scale models
20-foot propeller-research tunnel
5-foot variable-density wind tunnel
7 x 10-foot wind tunnel
4 x 6-foot vertical wind tunnel
15-foot free-spinning wind tunnel
2 high-velocity jet-type wind tunnels with throat diameters of 11 and 24 inches, respectively
19-foot pressure wind tunnel
7 1/2 x 3-foot refrigerated wind tunnel
12-foot free-flight wind tunnel
2,900-foot tank
Engine research laboratory
Flight research laboratory
Instrument laboratory
Shops and administrative buildings

In addition, undergoing construction were a structures research laboratory, a two-dimensional flow wind tunnel, a stability wind tunnel, a 16-foot high-speed wind tunnel, and a 20-foot free-spinning wind tunnel. At the same time, at the other end of the country a second research station (the Ames Aeronautical Laboratory)[107] was about to be built at Moffett Field, Sunnyvale, Calif., after a legislative history of almost a year including the original formal proposal by the NACA in

---

105. The NACA, 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 their experimental work in aeronautics. Soon, however, the Navy moved to the other side of Chesapeake Bay, while the Army moved to McCook Field in 1917. NACA, Annual Report (1919), p. 13.
106. NACA, Annual Report (1939), p. 38.
107. Named in honor of Dr. Joseph S. Ames, who retired from the chairmanship of NACA in October 1939. (Ibid., pp. 3-4.)

[redacted]

December 1938,[108] the blessing of the White House in February 1939, and a six-month struggle in Congress leading to the act of 9 August 1939.[109] With this new laboratory, the NACA was to be able to double its capacity for research.

Although appropriations were apparently no more easily obtained by the NACA than by the Air Corps before 1940, the work of the NACA was thoroughly, almost unanimously understood and appreciated by industry and the services alike. The Baker Board in 1934 had found the NACA "an outstanding institution" in its "pioneering work in aviation research";[110] the Howell Commission the next year credited the NACA with the recent "spectacular performance" of transports, and recalled that there had been "no better investment" since 1918 in the national interest than the subsidies to the NACA;[111] 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."[112]

---

108. Maj. Gen. Oscar Westover, Chief of the Air Corps, on 19 August 1938 had recommended to the NACA that a second laboratory be built somewhere in the interior or on the West Coast, to relieve "the congested bottle neck of Langley Field." For details on the selection of the site, see ibid., pp. 38-39.
109. 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 AAF Historical Studies: No. 22, Legislation Pertaining to the AAF Materiel Program, 1939-1944, pp. 106-14.
110. Baker Board, Report, p. 18.
111. Report of the Howell Commission, p. 227.
112. National Resources Committee, Relation of the Federal Government to Research, pp. 28-29.

[redacted]

The Air Corps in 1939, as always, regarded the NACA as its chief resource for basic aeronautical research. Legally the NACA existed for common use by all agencies--public and private--that 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 Navy Bureau of Aeronautics--rather than either the university or industry members of the Committee[113]--tended to exercise control by 1939. Both the services were, of course, represented on the main committee, the executive committee, and the various technical subcommittees; and in June 1939 this control was reinforced by the White House, which placed the NACA's research priorities and other policies under the arbitration of the joint Army-Navy Aeronautical Board.

In addition to the NACA and the Air Corps' own laboratories at Wright Field, there was a wide variety of experimental stations among the other federal agencies. While they were largely devoted to peacetime problems in 1939, nevertheless in total war they were convertible to research in the interest of national preparedness and defense. Their existence, their facilities, and their potential values were common knowledge among the many procurement agencies of the government. For example, there existed a comprehensive Directory of Inspection Services and Testing Laboratories of the Federal Government, compiled

---

113. Howell Commission (in its Report, 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 Fortune magazine (April 1942) stated that the NACA had been "dominated by the front office" of the aircraft industry. The Army and the Navy, however, seemed to be in control, especially after the White House order of June 1939.

[redacted]

a few years earlier (1935) by the Treasury Department's Procurement Division and the National Bureau of Standards. Taken together, government laboratories were expending about 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 Ordnance Department, and the Signal Corps Aircraft Radio Laboratory, all of which were working on Air Corps projects in 1939. Most notable was the Bureau of Standards, which had been helping the Air Corps for years. Hardly an annual report of McCook or Wright fields before 1939 had failed to acknowledge the Bureau's assistance. Among other things, the Bureau had experimented with instrument landing aids for several years; with the dilution of aviation lubricants since 1935; with isomeric paraffins for high-octane fuels since 1938; and, beginning in 1939, with other problems, including beryllium and protective coatings on magnesium. In April 1939 the Secretary of Commerce (Harry L. Hopkins) took the initiative to seek more projects for the Bureau of Standards from the armed services, and the Air Corps submitted nine additional projects to the Bureau, involving tests of stainless steel, aluminum alloys, countersunk rivets, and other problems.[114]

Industrial Resources for Research by 1939

The extent of scientific resources existing among industrial firms of America in 1939 was rather comprehensively known. First of all,

---

114. Memo for AS/W by C/AC, 17 April 1939, in AAG 400.112, Tests and Experiments.

[redacted]

several nation-wide inventories and surveys of industrial research were available. Among them[115] the most comprehensive census was one made by the National Research Council in 1938, continuing a periodical practice going back to 1920. It was based on a questionnaire addressed to industry, and published as a directory of Industrial Research Laboratories of the United States.[116] This survey gave specific data on the names and locations of laboratories, the names of the research directors, 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 NRC survey was examined statistically and critically in 1939-1940 by two other federal agencies, the Work Projects Administration and a subcommittee of the National Resources Committee.[117]

---

115. Included in other surveys, besides those discussed below, were the following. (1) An inventory by the National Bureau of Standards, published in July 1936 as a Directory of Commercial Testing and College Research Laboratories in Universities and Industrial Concerns (NBS publication M. 125). This directory, which covered university research also, had been issued in earlier editions, in 1927 (publication M. 90, April and Dec. 1927) and 1929 (publication M. 90 supplement), and came out in a wartime edition in 1942 (publication M. 171). (2) 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.

116. Published as National Research Council Bulletin No. 102 (1938). This publication was actually the sixth edition of a survey originally published by the NRC in 1920. See editions 1-5 inclusive, published as NRC Bulletins No. 2 (1920), 16 (1921), 60 (1927), 81 (1931), and 91 (1933), which give a comprehensive picture of the status and growth of commercially sponsored research between World War I and World War II. A later (seventh) edition was also published as NRC Bulletin No. 104 (Dec. 1940).

117. These evaluations were published in: George Perazich and Philip M. Field, Industrial Research and Changing Technology (Work Projects Administration, National Research Project Report No. M-4, Jan. 1940); 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 National Resource: II. Industrial Research (1941), pp. 173-87.

[redacted]

Among the trends in 1939 shown by these surveys were the growth of research laboratories as a phase of industrial expansion. Over 1,750 corporations in 1938 had research facilities collectively totaling 2,237 laboratories and 44,292 research personnel. This compared favorably with England's 435 or more laboratories,[118] and represented a tenfold expansion since World War I somewhat as is shown in the table on the following page. 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."[119] In terms of expenditures, American industry was spending about $100,000,000 a year, compared to only £2,000,000 by British industry.[120] In categories of scientific specialists employed, trends were apparent from 1920 to 1938 as shown in the table on page 72.

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

---

118. Estimate by Bernal in The Social Function of Science, pp. 107-08. In another place (p. 56) his estimate is 300 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.
119. Bernal, The Social Function of Science, p. 60.
120. Ibid., p. 56.

[redacted]

Growth of Industrial Laboratories and Research Personnel in the United States, 1920-1940[a]

Year	Number of companies	Number of companies reporting[b]	Number of laboratories	Total research personnel reported[b]	Percentage of personnel	
					Full-time	Part-time
1920	297	265	307	7,367		
1921	526	462		9,350	73.6	26.4
1927	999	926	1,147	18,982	74.5	25.5
1931	1,620	1,520	1,928	32,830	87.9	12.1
1933	1,562	1,462	1,854	27,567	89.7	10.3
1938	1,769	1,722	2,237	44,292[e]	97.4	2.6
1940	2,264[c]	2,350[d]	3,480[d]	70,033[d]		

a. Based, except for data for 1940, on Perazich and Field, Industrial Research and Changing Technology, (parts of Tables A-1, A-2, and A-4), pp. 63-65.

b. This excludes a small fraction of companies which, when originally surveyed by the National Research Council, 1920-1938, did not choose to report the size of their staffs, or reported in such fashion that the data could not be used. (Ibid., p. 57.)

c. National Research Council, Industrial Research Laboratories of the United States, Including Consulting Research Laboratories (7th ed.), p. ii. This figure is not exactly comparable with figures used by Cooper in the next columns.

d. Cooper, "Location and Extent of Industrial Research Activity in the United States," in National Resources Planning Board, . . . II. Industrial Research, pp. 173, 176.

e. Another estimate, by William A. Hamor of the Mellon Institute, was 25,000 in 1937. See National Resources Committee, I. Relation of the Federal Government to Research, p. 8.

[redacted]

Occupational Distribution of Industrial Research Personnel, 1921-1938[a]

Occupation	Over-all sample of Companies[b] 1921	1927	1931	1933	1938
Number of companies sampled	216	561	1,132	1,132	1,224
Number of research workers	2,358	6,766	15,057	13,080	19,797
Per cent of research workers	100.0	100.0	100.0	100.0	100.0
Director	7.8	5.2	5.6	6.3	4.1
Engineer	16.5	15.9	21.3	20.1	23.2
Chemist	33.3	27.2	25.8	27.3	28.5
Physicist	1.3	2.3	2.1	1.5	3.5
Metallurgist	1.1	1.2	2.2	2.3	3.3
Other professional workers	14.1	10.9	9.4	10.2	8.5
Laboratory assistant	19.6	26.0	18.4	17.7	16.9
All others	5.7	11.1	14.6	13.8	11.4
Unspecified	0.6	0.2	0.6	0.8	0.6

a. Based on tabulations published in Perazich and Field, Industrial Research and Changing Technology, p. 78, Table A-19.

b. Representative sample varying between 60 and 70 per cent of total companies reporting. Exactly how many or what percentage of the sampled companies were in the aeronautical and allied industries is not indicated in any of the related discussions in ibid.

[redacted]

the research staffs ranged in size from 172 to 4,000:[121]

Aluminum Co. of America
American Can Co.
American Cyanamid Co.
Atlantic Refining Co.
Bakelite Corp.
Bell Telephone Laboratories, Inc.
Chrysler Corp.
Consolidated Edison Co. of New York, Inc.
Crucible Steel Co. of America
Dow Chemical Co.
(E. I.) du Pont de Nemours & Co., Inc.
Eastman Kodak Co.
Electric Auto-Lite Co.
Firestone Tire and Rubber Co.
Ford Motor Co.
General Electric Co.
General Motors Research Corp.
General Motors Truck & Coach Co.
Goodrich (B. F.) Co.
Goodyear Tire & Rubber Co., Inc.
Gulf Research & Development Corp.
Hercules Powder Co.
Hudson Motor Car Co.
Humble Oil & Refining Co.
International Harvester Co.
Linde Air Products Co.
Monsanto Chemical Co.
Pennsylvania Railroad Co.
Philco Radio & Television Corp.
Pittsburgh Plate Glass Co.
RCA Manufacturing Co., Inc.
Republic Steel Corp.
Shell Development Co.
Sinclair Refining Co.
Socony-Vacuum Oil Co., Inc.
Standard Oil Co. (Ind.)
Standard Oil Co. of Calif.
Standard Oil Co. of La.
Standard Oil Development Co.
Sun Oil Co.
United Shoe Machinery Corp.
United States Rubber Products Co., Inc.
Universal Oil Products Co.
Western Union Telegraph Co.
Westinghouse Electric & Manufacturing Co.
Yellow Truck & Coach Manufacturing Co.

The expenditures for these largest firms compared favorably with those for 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 the same year.[122]

As to this concentration of research in large firms, the issue of large versus small corporations for aeronautical development was apparently

---

121. Perazich and Field, Industrial Research and Changing Technology, p. 68.
122. Science News Letter, 28 Oct. 1939, p. 280. In 1940 the Air Corps research budget rose sharply, from 3.5 to 10 millions.

[redacted]

not a significant one in the Air Corps in 1939. In 1935, however, the Federal Aviation (Howell) Commission had favored a few large aircraft firms rather than many small units as being better for the national defense, and had 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."[123] On the other side, there was the danger, in large corporate structures, that useful inventions and designs might actually be suppressed. Whether this situation applied also to the aircraft industry itself is a subject of conjecture. In any event, in related industries there were cases where new developments were not being fully utilized. Thus according to revelations in 1937 by the Federal Communications Commission, Alcoa 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.[124]

Whether or not the Air Corps Materiel Division knew of these particular national scientific surveys and was using them in 1939-1940, in the early months preceding national mobilization, it is certain that the Air Corps was fully cognizant of the extent of industry's potential

---

123. Howell Commission, Report, pp. 159-60. The Commission included both the development and production of air materiel 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 menaces to the development of good military aircraft" (pp. 161-62).

124. Subcommittee [Kilgore] on Technological Mobilization, Senate Committee on Military Affairs, Hearings . . . S. 2721, Oct.-Dec. 1942, especially pp. 215-16, 285, 380-475; and Bernal, The Social Function of Science, pp. 143, 152-53.

[redacted]

both for development and for production of new airplanes and aeronautical equipment. The aircraft and allied industries--rather than Wright Field or the universities or even NACA--were and had been ever since before World War I the Army's basic source for applied research and experimentation leading up to new materiel. Although a few important airplanes were actually built by the Engineering Division at McCook Field, chiefly between 1917 and 1922, and while university laboratories had contributed to a number of the Army's aeronautical developments before 1939, by far the largest bulk of the work was done by industry under contract to the Air Corps, in 1939 as in virtually every other year back to the very origins of the Army's air arm in 1907. Thus, during the fiscal year beginning 1 July 1939, over 60 per cent of the total Air Corps research budget--6 out of 10 millions--was actually being turned over to industry as payments on contracts for experimental or service-test airplanes, engines, propellers, and other equipment. This significantly high percentage was probably typical of the entire history of the Air Corps. To appreciate the scope of these subsidies to industry is fundamental to any understanding of the research and development policy of the Air Corps.

Ever since World War I, if not before, it had been a fundamental policy of the Air Service to regard experimental contracts as a means of giving support--financial and otherwise--to the aeronautical industries. For example, in 1919 the industry was in danger of being "snuffed out" by cancellations of war contracts and the return to a peacetime economy, during the "infancy" stage and before the existence of an air transport

[redacted]

industry or other significant commercial outlets on which aeronautical manufacture could thrive. The Air Corps, the Navy Bureau of Aeronautics, and their representative on the NACA all saw clearly and spoke frequently on the fundamental interrelationship between full government support and the growth of an industry which possessed such an enormous potential for national defense. The NACA had spoken warmly in behalf of government support in 1919,[125] and regularly thereafter. In 1923, the Chief of the Air Service had warned of the danger to national preparedness of an insufficient research budget: "The aeronautical industry in the United States, built up to large proportions during the war, has shrunken rapidly and is now facing extinction. Until commercial aerial transportation becomes a fact, the only demand for such equipment originates with the military branches of the Government."[126]

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

---

125. NACA, Annual Report (1919), p. 40.
126. Memo for Maj. Pettis, Office of AS/W, by Chief of Air Service, 28 Feb. 1923, in AAG 475.73, Aeronautical Equipment.

[redacted]

delivery to the Air Corps. All of this pressure, pleading, and urging was directed primarily toward the encouragement of industry research and design which were of value to the Air Corps.

When war broke out in Europe in 1939, the Air Corps in its dealings with industry was on very firm ground, with a strong nucleus of aircraft and allied industries alerted for coping with the developing international situation. Of the 125 or more aircraft, engine, and other aeronautical manufacturers in 1939, the following 34 had substantial experimental design departments and laboratories:[127]

Airplanes

Curtiss-Wright, Buffalo, N. Y. (staff of 5)
North American Aviation, Inc., Inglewood, Calif. (6)
Stearman Aircraft Co., Wichita, Kans. (3)
United Aircraft Corp., East Hartford and Bridgeport, Conn. (1?)
Vultee Aircraft Division of Aviation Manufacturing Corp., Downey Field, Calif. (5)

Engines

Continental Motors Corp., Detroit, Mich. (staff of 16)
Lycoming Manufacturing Co., Williamsport, Pa. (6)
Pratt & Whitney Co., Hartford, Conn. (8)

Accessories

Aircraft Radio Corp., Boonton, N. J. (staff of 12)
Aluminum Co. of America, Pittsburgh, Pa. (202)
American Telephone & Telegraph Co., Inc., N. Y. (staff ?)
Bendix Products Division of Bendix Aviation Corp., South Bend, Ind. (17?)
Berry Brothers, Inc., Detroit, Mich. (16)
Champion Spark Plug Co., Toledo, Ohio (29)
Dow Chemical Co., Midland, Mich. (13)
Eclipse Aviation Corp., Bendix, N. J. (18)
Fafnir Bearing Co., New Britain, Conn. (15)
Fairchild Aerial Camera Corp., Jamaica, N. Y. (36)

---

127. Data in Aircraft Year Book (1939), pp. 282-463, compared with Industrial Research Laboratories of the United States (1938).

[redacted]

Firestone Tire & Rubber Co., Akron, Ohio. (staff ?)
General Electric Co., Schenectady, N. Y. (306)
Goodrich Co., B. F., Akron, Ohio (staff ?)
Leece Neville Co., Cleveland, Ohio (12)
Norma-Hoffman Bearings Corp., Stamford, Conn. (7)
R.C.A. Manufacturing Co., Inc., Camden, N. J. (469)
Shell Petroleum Corp., St. Louis, Mo. (78?)
Sinclair Refining Co., N. Y. (125)
SKF Industries Inc., Philadelphia, Pa. (11)
Socony-Vacuum Oil Co., Inc., N. Y. (staff?)
Sperry Gyroscope Co., Inc., Brooklyn, N. Y. (25)
Standard Oil Companies of N. J. (10), Pa. (staff?), and La. (53)
Thompson Products Inc., Cleveland, Ohio (14)
Walter Kidde & Co., N. Y. (5 or more)
Western Electric Co., N. Y. (staff ?)
Wilcox-Rich Division of Eaton Manufacturing Co., Detroit, Mich. (6)

This list excluded some of the most prominent Air Corps contractors, who for one reason or another did not report their design or experimental staffs: Boeing, Consolidated, Douglas, Lockheed, and Martin, for airplanes; Allison and Wright, for engines; Curtiss and Hamilton Standard, for propellers; Kollsman and Pioneer, for instruments. Furthermore, the total research staffs of the aeronautical industries, reported at only 1,500, was a considerable understatement because, for aircraft firms, it excluded most of the aircraft design staffs and chiefly included only the wind tunnel technicians and test experts. These statistics represented, however, a considerable growth over the years of peace since 1918, a fivefold growth from the 30 or more firms with research and design departments that existed at the close of World War I.[128]

In addition to direct applied research on airplanes and aeronautical equipment, the Air Corps also had an appreciation of industry's resources

---

128. Research Laboratories in Industrial Establishments of the United States . . . (National Research Council, Bulletin No. 2, March 1920); and Aircraft Year Book (1920).

[redacted]

for basic research. Aside from the field of aeronautics, where the government-controlled NACA was supreme, basic research was a not uncommon enterprise of some of the larger corporations. The Air Corps pointed out that of these firms, the work of Alcoa, General Electric, and Eastman was best known and appreciated. Their research findings, the Air Corps stated in 1940, "quite often compare favorably with those obtained by the Governmental agencies working on pure research"; and while specific evaluation was difficult because of trade secrets, the Air Corps favored "the maintaining of old and the birth of new commercial research and development organizations of this type."[129]

Air Corps contracts had been the method for stimulating aeronautical experimentation by industry and for keeping industry in condition for a national emergency. Contracts for military planes rather than subsidies to commercial air transportation were regarded as of greatest importance for the research program. More specifically, the easy assumption that commercial transports were quickly "convertible" to combat use had been perennially denounced by the Air Corps. The Drum Board in 1933 and the Federal Aviation (Howell) 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

---

129. Memo for Inspector General by C/AC (written by Maj. E. M. Powers), 18 April 1940, in AAG 400.112, Test, Development Work.

[redacted]

policy had been to permit the contractor to amortize the cost of experimental construction with income from future quantity-production orders. Both parties had been critical of this "competitive bidding" procedure. Industry occasionally objected to the unduly heavy risk in undertaking large projects, such as a bomber or pursuit design which might utterly fail in the evaluation; and the Air Corps realized that the high cost of experimental aircraft, if amortized, would adversely affect the purchase of future production quantities by raising production prices. If not amortized, the cost might be an inflated one, in effect, in those cases where a given model might also later be amortized by quantity sales to other customers, such as the airlines, the Navy, or the export market.[130] Industry and Air Corps objections were echoed by the Baker Board in 1933 and the Howell Commission in 1935, both of whom favored flexible contract procedures, purchase by negotiation, and a system of fixed prices, bonuses, and penalties. In November 1938 the Air Corps asked Congress for authority to negotiate experimental contracts as an alternative to competitive bidding,[131] 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

---

130. 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 memo for C/AC by Chief, LD (written by Maj. B. E. Meyers), 21 March 1939, in AAG 334.8, ACTC, bulk files.

131. Memo 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 Materiel Program, 1939-1944, p. 82.

[redacted]

experimental research funds [i. e., 10 millions]," were pressing General Arnold to carry out a more flexible policy.[132] Maj. B. M. Meyers, Budget Officer at Wright Field, surveying the situation historically, recommended a more forthright financial policy in order to mobilize the experimental resources of the aircraft industry: "Industry exists for profit . . . [and] will depend on experimentation only where a potential profit exists. Industry as it exists today cannot [be expected to] deplete capital through experimentation in the interest of national defense."[133] Most aeronautical firms were actually making substantial profits on contracts for the Air Corps. These amounted to about 12.55 per cent on all Air Corps contracts in 1939: 10.86 per cent on airplanes, 9.17 per cent on engines, and 24.21 per cent on other air equipment.[134] But Wright Field was concerned that unpredictable and excessive development costs might weaken some elements of the industry, including at least two of the airplane firms, some of the engine firms (both small and large),[135] and the propeller companies.[136] The remedy lay in negotiated contracts and orderly budget planning. The act of 3 April 1939 permitted some limited flexibility in the

---

132. Memo for Chief, ID by C/AC, 1 March 1939, in AAC 400.112, Tests and Experiments (filed under 22 March 1939).
133. Memo for C/AC by Chief, ID (written by Maj. B. M. Meyers), 21 March 1939, in AAG 334.8, ACTC, bulk files.
134. Legislation Relating to the AAF Materiel Program, 1939-1944, p. 85.
135. Memo for C/AC by Chief, ID (by Maj. B. M. Meyers), 21 March 1939, in AAC 334.8, ACTC, bulk files.
136. Military-financed propeller research was essential. Because of the "limited market . . . from the standpoint of money value, private industry cannot be expected to do the amount of highly experimental research that the situation demands." (Memo, 10 May 1939, p. 11, in WCS file on R&D Program, F.Y. 1941.)

[redacted]

purchase of experimental models that had failed in design competitions, and an act of 13 July 1939 permitted some negotiated purchasing without advertising, but only when secrecy was involved.[137] Further legislation of 5 March and 2 July 1940 extended the authority to negotiate, and after America officially entered the war in December 1941, AAF negotiation authority was finally made complete, except for subsequent modifications affecting re-negotiation and profit control, a separate problem outside the scope of this study.[138]

University Resources for Research by 1939

University facilities in applied research were of course vastly smaller than industry's, because of the basic character of the national economy, in which research was an important tool of industry for the development of commodities for sale in the competitive market. Most of the university laboratories were devoted to fundamental phases of the physical sciences, and their projects were sponsored by various sources--industry, government, foundations, or the university itself. No detailed survey of the scientific potential in universities was available in 1939, but a few partial inventories did exist: The Bureau of Standards in 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

---

137. 53 Stat. 560, 1000.
138. For the legislative history of Air Corps negotiated contracts procedure in 1939-1940, see Legislation Relating to the AAF Materiel Program, 1939-1944, especially pp. 82-98, 101, 152.

[redacted]

research.[139] The latter survey revealed some important general information on universities: that the trained scientific personnel of universities totaled 9,100; that research expenditures per year totaled $51,000,000, in some cases constituting 25 per cent of a university's total income; and that the achievements of American universities in pure science had not been so "remarkable" as those of Europe. The survey, however, was not detailed. Only 60 of 200 institutions had replied to the Committee's questionnaire; scientific apparatus and plant facilities were not covered; and the potential for national defense was barely mentioned. Furthermore, none of these surveys was specific enough--as to facilities, subjects of research, or manpower--for administrative use in the planning of a military research program.

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 per cent 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 per cent ($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.[140] Indirectly, however, the Air Corps had

---

139. National Bureau of Standards, Directory of Commercial Testing and College Research Laboratories in Universities (NBS publication M125, July 1936); C. S. Marsh, ed., American Colleges and Universities (1938); and Raymond M. Hughes, "Research in American Universities and Colleges," in National Resources Committee, Relation of the Federal Government to Research (1939), pp. 165-93.

140. Tabulation, F.Y. 1940-1944 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 AAG 400.112, Tests and Experiments.)

[redacted]

several university projects under way in 1939, notably a small rocket and a jet propulsion project at the California Institute of Technology, sponsored by the National Academy of Sciences (NAS),[141] in addition to various NACA-university contracts which had existed since 1935 and were costing about $25,000 annually.[142]

It was apparently an assumption in 1939 that the Air Corps, if it utilized university research at all, would normally contract for it through the NACA and the NAS rather than directly. Neither the Baker Board in 1933 nor the Howell Commission in 1935 included references to the Air Corps in their recommendations on university research on aeronautics, an especially significant omission because a university administrator sat on each of the boards. Similarly, both the Kilner Board and the NACA research subcommittee in 1939 implied that university research for the Air Corps would be handled indirectly through the NACA. Yet the Materiel 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

---

141. Other NAS "basic research" projects, presumably to be placed with universities, were covered in an AC-NAS contract (W535-ac11707) 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 AAG 337, Conferences.

142. NACA, Annual Report (1939), p. 39. The NACA proposal in 1939 to expand this university program tenfold met the "strenuous objection" of the Budget Bureau. See NACA Executive Committee, Minutes, 16 Nov. 1939, pp. 2-3, in AAG 400.112, NACA.

[redacted]

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.

The Air Corps student at M.I.T., Capt. Alfred R. Maxwell, who was prominent in bombardment development,[143] saw in the aeronautical departments of America's best technical schools a resource that the Air Corps ought to tap more fully, and he sent the Materiel Division his views and recommendations.[144] He was "surprised" at the "extensive" aeronautical research facilities at M.I.T., whose work "certainly compares favorably with that of the NACA," and warned that while the Air Corps was taking "little advantage" of it, the Navy, the CAA, the NACA, the Corps of Engineers, and firms like Sperry and General Electric all had "successful projects" under way there. Generalizing about M.I.T. and similar institutions, Captain 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,

---

143. Captain Maxwell (later Colonel Maxwell, Director of Bombardment, and Chief of OC&R Bombardment Branch, 1942-1944) 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, bomb sights, 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 AAG 210.66, Detail Officers--Civilian Educational Institutions; memo for Commandant, AC Engineering School, by Maxwell, 31 March 1940, in AAF 201, Maxwell, A. R.; and memo for Decorations and Awards Branch by AC/AS, OC&R, 9 Sep. 1944, in ibid.

144. Capt. Alfred R. Maxwell to Brig. Gen. G. H. Brett, Chief, MD, 29 Jan. 1940, in AAG 400.112, Tests and Experiments.

[redacted]

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

Maxwell's estimate of the university research situation was read by various officers in Air Corps headquarters, and General Arnold ordered it sent to the NACA's new "Coordinator of Research,"[145] rather than to Wright Field. Apparently it was discussed in the NACA meeting two days later, when the NACA was directed by its Executive Committee to make a nation-wide survey of research facilities of schools, universities, and other "individual organizations" throughout the country, as well as an inventory of potential research projects at Wright Field

---

145. Maj. A. J. Lyon, Exec., LD to Capt. Alfred R. Maxwell, 5 Feb. 1940, in ibid.

[redacted]

(and presumably at the naval aircraft factory as well) that might be suitable for allocation to universities.[146]

This inventory in February 1940 was apparently the first usable survey of aeronautical research laboratories in universities in recent years,[147] and while it remained unpublished, it contained actual facts and figures to bolster the Lindbergh Committee's generalizations of six months before, and provided the Air Corps with an estimate of America's scientific potential in the aeronautical fields. Substantial laboratory equipment and trained personnel were found to exist in 75 educational institutions, many of which were later visited by NACA officials. In subsequent months, 30 research projects were to be initiated by the NACA, with some of them in the field of aerodynamics (6); structures (10); materials (5); and power plants (9). Meanwhile, the Air Corps was also to expand its university program.

Control and Coordination of Military Research by 1939

Governmental control and supervision over scientific work in America was nonexistent in 1939 in terms of a nation-wide mobilization of scientists and laboratories for national defense. This mobilization was not to come until 1940. There was nothing in the United States comparable to the German or Italian dictatorship over industry and education, nor anything comparable to the Soviet collectivist system for the management of

---

146. TI-119 (prepared by Capt. B. N. Chidlaw, MD), 23 Feb. 1940, in ibid.
147. The Directory published in 1936 by the National Bureau of Standards (previously cited) included "college research laboratories" but omitted such well-known facilities as C.I.T. and M.I.T.; and its format, arrangement, and code names made it difficult to use.

[redacted]

technology and production, nor even anything comparable to the nationalized aircraft industry of France of 1936. Nevertheless, even in the United States in 1939 there was certainly much more control over science by governmental agencies than was publicly admitted by many of the vocal spokesmen for industry and science. The nature and extent of government control and coordination of industrial, university, and government laboratories had been comprehensively examined by the National Resources Committee in 1938,[148] and the examination revealed a rich and varied tradition of government coordination of research going back at least as far as the patent system established by the Constitution, or the agricultural experiment stations begun in 1862. It is a totally inaccurate legend that scientists in universities and industry were working "freely," uninfluenced by government guidance and impulses, whether for humanitarian, national-preparedness, or other social purposes.

Specifically, the Air Corps in 1939, as discussed earlier, was supervising aeronautical research in numerous ways. This control was exercised in specific situations and for specific problems: discretion in the choice of this or that private organization to undertake a research project, especially where competitive conditions did not exist; control over the allocation and expenditure of funds; engineering and testing of specific experimental articles; and the final evaluation of the end product itself. There was nothing unusual or sinister in this traditional relationship between the military and the scientist. It

---

148. See its publication, Relation of the Federal Government to Research.

[redacted]

was such a common relationship, so well founded in historical precedent in the American economy, that it was not even consciously an issue in 1939.

Nor was this military-civilian, governmental-private relationship necessarily "stifling" on the development of new airplanes or other equipment. The hackneyed historical legend, that new weapons have usually been developed in spite of the "traditional stupidity and conservatism of military authorities,"[149] if it is correct at all, was hardly correct for Army aviation between World War I and World War II, when military requirements had normally been somewhat ahead of the state of the art and when the Air Corps research budget had subsidized most of America's advanced aeronautical developments. Conservatism here and there did exist, perhaps, but far from being peculiar to the military, it was likely to be equally characteristic of an engine firm,[150] a university engineering department,[151] a government laboratory, or at least

---

149. Bernal, The Social Function of Science, p. 182. Bernal indirectly contradicts this statement, however, with specific examples cited elsewhere, where he "bemoans" the efficient but "prostituted" use of science by the military. Other critics have uttered the same observations as to military conservatism toward new weapons, including George W. Gray and Waldemar Kaempffert.

150. The apparent resistance to jet propulsion research by some of the conventional engine firms about 1940-1942 is an example. The lag in the commercial application of new inventions is also interesting in this connection. See S. C. Gilfillan, "Prediction of Inventions," in National Resources Committee, Technological Trends and National Policy . . . (H. Doc. No. 360, 75 Cong., 1 Sess., pt. 2, pp. 15-23.

151. 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, pp. 77-78.

[redacted]

portions of each. In whatever type of institution, both conservative and liberal attitudes were likely to prevail side by side, and the development of new weapons was comparably affected.

The issue of "control" was not whether there should or should not exist governmental supervision over scientific research, but rather how extensive it should be, and in which particular governmental agency that control should be vested. As the responsible procurement agency for air materiel for the Army, based on act of Congress and Army regulation, the Air Corps in 1939 was obviously interested in keeping the closest control over its research contracts with private organizations, as well as over the relevant research projects in other governmental laboratories. To be interested in anything less than close supervision and control would have been to shirk responsibility and to abdicate its fundamental materiel 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 was 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:[152]

> . . . a coordinating function by means of subcommittees consisting of experts from the Government agencies and from various branches

---

152. J. C. Hunsaker, "Research in Aeronautics," in National Resources Planning Board, . . . II. Industrial Research, p. 136. Professor Hunsaker, at that time (1940) was in charge of the Department of Aeronautical Engineering at M.I.T., in addition to being a member of NACA. Later he became chairman of the NACA.

[redacted]

> 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 NACA since 1918 had been collecting information and data on the progress of foreign aeronautical developments, through its "scientific attache" in Paris as well as by other means. None of these coordinating activities were new in the NACA 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 government subsidies were defended as an "effective," "economical," and "democratic" procedure for furthering "what has become an international competition" in national preparedness.[153]

The Air Corps in 1939 was inclined to defer to the NACA for the coordination of the fundamental phases of aeronautical science, since the Air Corps (together with the Navy Bureau of Aeronautics) could effectively control the Committee's policies and decisions, not only through their membership on it and on its subcommittees, but also through the joint Army-Navy Aeronautical Board, which was given emergency jurisdiction over the NACA in June 1939.[154] In accepting this situation,

---

153. NACA, Annual Report (1939), p. 3.
154. The White House on 29 June 1939 approved a proposal made in August 1938 by the NACA Special Committee on Relationship of [NACA and] National Defense in Time of War, of which Maj. Gen. Oscar Westover, then Chief of the Air Corps, had been chairman. See NACA Executive Committee, Minutes, 15 Sep. 1939, pp. 9-10, in AAG 400.112, NACA.

[redacted]

however, General Arnold had warned that fundamental research should not be rigidly separated from "applied" and "production" research by a "Chinese wall," and that if the NACA should become the coordinator of fundamental research, it needed "new blood and [should be] expanded sufficiently to assume this function."[155] Subsequently a Director of Coordination had been established in the NACA in June 1939, with the blessing of both the Executive Committee and the special Lindbergh Committee, and in January 1940 the Coordinator (S. Paul Johnston) was appointed.[156] How extensive or effective this coordination would be was still doubtful. The Air Corps, even with military control of NACA assured, in general preferred direct collaboration with contractors working on its projects, unless the research project clearly had broad Army-Navy-commercial aspects. A further reason for direct liaison, suggested by Captain Maxwell at M.I.T. and probably widely accepted in the Air Corps, was that the engineering students and faculties tended to regard the NACA as "rather impersonal and overcritical," and "only a source of technical literature," while the Air Corps was "living and glamorous to most, and a goal of quite a few."[157]

Any coordination by the NACA, furthermore, was concerned only with fundamental research, and only in the fields of aerodynamics,

---

155. Memo for AS/W by C/AC, 29 Jan. 1939, in AAG 400.112, Tests and Experiments.
156. NACA Executive Committee, Minutes, 23 June 1939, and preliminary report of Lindbergh subcommittee [about 24 Aug. 1939], both in AAG 400.112, NACA; and NACA, Annual Report (1940), pp. 21-22.
157. Capt. Alfred R. Maxwell to Maj. A. J. Lyon, 19 Feb. 1940, supplementary to his earlier letter of 29 Jan. to Gen. Brett, previously cited; both in AAG 400.112, Tests and Experiments.

[redacted]

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

Beyond these Army-wide controls and a few formal but insignificant Army-Navy channels on research, there existed in 1939 a skeleton organization for research coordination that might be convertible to national defense purposes. This organization was the National Research Council, which had been the 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, totaling about 220, was rather broad, representing 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 large. Its various divisions and subcommittees totaled about 1,150 additional

[redacted]

scientists and professional men.[158] In addition to its supervision of a limited number of technical projects for various federal agencies, it also disseminated information useful for 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 National Research Council, at the request of the National Resources Committee, was going beyond this inventory to make "a study of the capacity of industrial corporations in the United States for scientific research, and especially the trends of the research undertaken by the laboratories of these firms." This survey, while it was apparently not made for national defense purposes, did contain many conclusions easily convertible into recommendations on national preparedness on the scientific front.[159]

In 1939 the National Research Council and its parent body, the National Academy of Sciences, were perhaps a "passive" influence so 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 actively to seek out scientific problems confronting the military procurement services; and they usually spoke with

---

158. Albert L. Barrows (Executive Secretary, NRC), "The Relationship of the National Research Council to Industrial Research," in National Resources Planning Board, . . . II. Industrial Research, p. 365. See also historical statements on "National Research Council," in Journal of Applied Physics, Aug. 1943, pp. 378-79; and The Government's Wartime Research and Development, 1940-44 (Senate Subcommittee Report No. 5, 79 Cong., 1 Sess.), pp. 234-42, 325-26.

159. The end product of this survey was the 370-page report of the National Research Council to the NRPB, December 1940, entitled Research—A National Resource: II. Industrial Research (1941). Some of its conclusions and facts have already been quoted.

[redacted]

some pride that their mission was "not" to volunteer and to seek out projects of interest to the government.[160] 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 turning over these problems and the limited funds supporting them, the Air Corps was unwilling to go. Thus, the Air Corps, when asked early in 1940 whether its liaison with the NRC could be improved, acknowledged the value of NRC contacts with scientists and pointed to the list of projects mentioned above, but reiterated its fundamental policy of "direct collaboration" with outside agencies. Illustrating its position by the technical problem of bombing-through-overcast (BTO), the Chief of the Air Corps pointed out the need for close, but direct, collaboration between the military and the civilian scientist in these phases: (1) to determine the scope of the problem; (2) to summarize the probable means and methods of its solution, and to agree on "the most practical approach"; and (3) to determine whether a solution were "feasible" if applied to military aviation, and if applied, whether the "application" would be "practicable" from tactical and production standpoints. These phases of the problem, he urged, required "open round-table discussions between the scientists and the practical engineer," and "direct collaboration" with outstanding

---

160. Later testimony as to the passive character of the NAS and the NRC are given in Hearings . . . S. 2721 before the Senate Sub-committee on Technological Mobilization, Oct-Dec. 1942, pp. 8, 12, 14, 76-77, 368. One of the witnesses, M. M. Whitaker, went further (p. 357), to criticize the NAS as conservative and "self-perpetuating," an "august body . . . of mature years . . ., crystallized in their ideas and their viewpoint . . . conservative."

[redacted]

authorities in physics, aerodynamics, optics, and metallurgy.[161] 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 were 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.[162] The bill was never passed. A later congressional proposal, early in 1939, for a more limited body, one primarily for "military aircraft engineering" but covering both the Army and the Navy, was likewise rejected, this time after objections by the two services jointly as well as by the Air Corps separately.[163] 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 that would reduce direct collaboration or add to the hierarchy of supervisory agencies. The existing organization was deemed adequate for

---

161. 1st ind. (AG letter 381 National Defense [3-11-40], 14 March 1940), C/AC to TAG, 11 April 1940, in AAG 400.112, Test, Development Work.
162. Memo for AS/W by C/S (Gen. Malin Craig), 3 Sep. 1938, in AAG 400.112, Tests and Experiments.
163. Legislation Relating to the AAF Materiel Program, 1939-1944, pp. 104-05; and NACA Executive Committee, Minutes, 23 June 1939, p. 4, in AAG 400.112, NACA.

[redacted]

insuring Air Corps control over military requirements and research policy and permitting the ultimate execution of scientific work by the designers and builders of experimental models. Such was the situation as to scientific coordination a few months before the establishment by the White House of a federal-wide National Defense Research Committee.

[redacted]

[redacted]

Chapter IV

WARTIME RESEARCH AND DEVELOPMENT POLICIES, 1939-1944

Changing Military Requirements, 1939-1944

The Kilner Board's five-year program of June 1939, and its conservative modification by the Air Board in September 1939, continued into 1940 as Wright Field's immediate and long-term goals. A few additions to the program were made 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 1 July 1940.[1] By the spring of 1940, however, the pressure was for the immediate rather than the ultimate improvement of Army aviation, chiefly for the rapid "modernization" of existing standard-production models. British and German operations since September 1939 were showing the need for such aids as armor protection, leakproof tanks, turrets, de-icing equipment, and (for pursuits) droppable fuel tanks and auxiliary bomb racks. These needs, reported by military attachés, were underscored by the observations of Lt. Col. George C. Kenney while in England, and by a British air marshal's statement about April 1940, that "were the Army Air Corps to send its airplanes across into

---

1. 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.

[redacted]

Germany today not one of them would return."[2] General Arnold, impressed by these observations, ordered a re-evaluation of the entire research program by a special board headed by Maj. Gen. Delos C. Emmons (Commanding General of the GHQ 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.[3] It added virtually nothing new to the airplane and equipment developmental objectives of 1939 except to revive barrage balloon development, which itself was another element in the defensive equipment. Furthermore, as England's strategic situation became worse, in the dark days of May and June 1940, the immediate production needs of the Air Corps became more and more pressing, and momentarily threatened the entire research program--the long-term goals as well as the immediate developmental objectives. Thus, on 7 May 1940, when the Germans were already in Norway but not yet in the Low Countries, General Arnold could still cable from Panama (where he was on a temporary mission) to urge that wartime research and development be vigorously pushed in the forthcoming defense of the budget estimates.[4] Five weeks later, however, with British troops evacuated from Dunkirk and with France virtually conquered, the strategic situation

---

2. Memo for Maj. Gen. Delos C. Emmons, CG, GHQAF by Colonel Kenney (?), 23 April 1940, appointing Emmons president of the Board to re-examine the Research and Development Program. (Copy in AFSHO.)
3. "Report of Board of Officers [Emmons Board] . . . Personnel Order 104, . . . May 2, 1940." (Copy in AFSHO.)
4. Teletype, Maj. Gen. H. H. Arnold, C/AC, to Brig. Gen. B. K. Yount, Acting C/AC, 8 May 1940, in AAC 381.4, War Plans, National Defense.

[redacted]

had become so bad that General Arnold ordered what was virtually a reversal, in favor of quantity production at all costs. Because of the "condition of world affairs and the will of the American people for adequate defense," he said, the first priority must be the "continuous production of current types of airplanes for the Army," while research and development must be given "the lower priority . . . consistent with the [above] primary mission."[5] Higher authority, probably including the White House and Congress, was involved in issuing this policy, and Arnold "personally" assured the Chief of Staff on 14 June 1940 that "every effort" was being made to standardize equipment, increase production, expedite deliveries, and "defer our present research and development program"; and he hinted that some phases of the latter might even "be transferred to some other Governmental agency," presumably a reference to the new National Defense Research Committee. D-day had been set at 1 October 1941 by the Chief of Staff, and the airplanes needed, General Arnold stated, were "not those which will be produced four years from now, but those to be delivered within the next six months or a year, certainly not more than two years hence."[6]

The research program, however, was not scrapped. It was merely postponed temporarily in specific cases where a manufacturer's production

---

5. Memo for Chief, MD by C/AC, 6 June 1940, in AAG 452.1-17, Airplanes--Manufacture of. General 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'." (Memo for Maj. M. E. Gross by Maj. B. W. Chidlaw, both in MD, 1 July 1940, in M&S file on R&D Program, F.Y. 1941.)
6. Memo for Exec., OCAC by C/AC, 14 June 1940, in AAG 400.112, Tests and Experiments.

[redacted]

for the Air Corps would be interrupted by work on experimental contracts. The 10 most important airplane projects were selected by the Emmons Board (which had meanwhile been "educated" by an inspection trip to Wright Field); and priorities, based both on strategic needs and on manufacturers' capacities for experimental work, were assigned in June 1940:[7]

1. 5,333-mile very heavy bomber (B-29, 30, 32)
2. 2-engine interceptor (Lockheed XP-49, Grumman XP-50)
3. 2,667-mile medium bomber (North American XB-28, 28A)
4. Escort fighter (Lockheed XP-58)
5. 1-engine interceptor (Vultee XP-54, Curtiss XP-55, Northrop XP-56)
6. Navy dive bomber
7. Light bomber (Martin XA-23)
8. Long-range bomber (8,000-mile range)
9. Observation airplane
10. 2-engine trainer (Beech AT-7A)

These priorities were not to be rigid, because of "the constantly changing military situation abroad," the capacity of the industry "to absorb . . . experimental development without interference with the approved procurement program," and the extent to which the current developmental projects were being successfully completed.[8] 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, however, continued to be threatened by the production program. In September 1940 "certain aircraft manufacturers"

---

7. Memo for Maj. Gen. H. H. Arnold, C/AC by Maj. Gen. B. K. Yount, Asst. C/AC, 7 Oct. 1940, attached sets of priority schedules, and comments by Maj. B. M. Chidlaw, ID, 20 Sep. 1940, all in AAG 452.1, Airplanes, General.
8. Memo for TAG by Brig. Gen. B. K. Yount, Acting C/AC, 17 Aug. 1940, in M&S file on R&D Program, F.Y. 1942. (Based on memo for C/AC by Chief, ID, 17 Aug. 1940, copy in AFSHO and in AAC 400.112, Research and Development Programs.)

[redacted]

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."[9] At the same time the NACA laboratories also were affected: wind tunnels and other facilities were diverted from "basic research" in order to concentrate on improving the performance and correct the defects of current production models.[10] By 1941 the stabilization of industry was well under way toward achievement, and experimental work could be resumed in more orderly fashion. The policy of September 1940 was reversed, the aircraft industry was asked for its test programs for all experimental aircraft on contract,[11] and the last major threat to research and development during the war was removed.

Research and development objectives continued to be affected, in 1940 and 1941, by British experience with the new and improved airplanes and equipment and tactics in the Anglo-German air war. In 1940, the turret and armament mission by Lt. Col. Grandison Gardner and Maj. F. O. Carroll[12] and the radar mission by Maj. A. W. Marriner, if they did not

---

9. Memo for Chief, MD by C/AC, 13 Sep. 1940; referred to Wright Field as TI-342, 16 Sep. 1940; both in AAG 452.1-17, Airplanes--Manufacture of.
10. MD letter to all contractors, 8 May 1941, in AAG 400.112, Test, Development Work.
11. Ibid.
12. Report by Gardner and Carroll, 1 July 1940, quoted in draft ATSC historical study, "Power Turrets [1917-1944]," Chap. V, n. 24.

[redacted]

reveal actual gaps in the Air Corps research and development program, at least underscored the greater urgency of certain phases of materiel over others, and contributed suggestions as to more fruitful avenues of research. Certainly the work on turrets and radar detection and ranging were all prosecuted with greater vigor as a direct result of these Air Corps missions abroad. In the next year, the mission of General Arnold to London (in April-May 1941) likewise raised the priorities for high-altitude pressurizing equipment, jet propulsion, controllable bombs, gliders, photography, and external fuel tanks for range extension, at the same time confirming Air Corps superiority of turbo-superchargers, cannon installations, .50-caliber guns, bomb sights, and air-cooled engines.[13] After June 1941 refinements of the program were influenced by the Special Observer Group headed by Maj. Gen. James E. Chaney (the Chaney Mission, or SPOBS), even though this mission was preoccupied not with materiel but with tactical planning for future American participation with England in the war against Germany.[14] 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.[15]

---

13. Many but not all of General Arnold's conversations and deliberations are described in his cablegrams from London to Washington, in AAG 311.22, Cablegrams, filed under 5 May 1941. See also Edward Warner to T. P. Wright, writing from London, 22 April 1941, in AAG 381.3, Lend-Lease Aid, filed under 12 June 1941; and teletype, WF to Chief, MD, 13 June 1941, copy in M&S file on R&D Program, F.Y. 1942.
14. Interview with a former member of SPOBS, Brig. Gen. H. H. McClelland, ACO, about 9 Jan. 1945. The air technical activities of SPOBS were directed by Col. A. J. Lyon. A fuller discussion of this mission is included elsewhere in this study.
15. Col. Ira C. Eaker, "Report on Trip to England," 30 Aug.-1 Oct. 1941, 2 vols., in AFSHO, "Col. Moore's files."

[redacted]

In addition to the influence of British tactical and experimental experience on Air Corps materiel development was the effect of the general strategic and political situation on the Air Corps program as a whole late in 1940 and in 1941, before America officially entered the war. The research and development program of 1939, "thrown for a loss" early in 1940 by the immediate need for quantity production, gradually came back into full stature later in 1940. By 1941 the original program was fully revived and expanded. American development was being stimulated not only by specific ideas from Britain, but also by the changing strategic and political situation which called for closer collaboration with the Allies: the increasingly liberal policy of releasing advanced models to the British and other potential allies in March 1940; the establishment of the Army-Navy-British Aircraft Committee in September 1940 (later renamed the Joint Aircraft Committee); President Roosevelt's "fireside" announcement on 29 December 1940 that America would become the "arsenal of democracy," a concept applicable as much to development as to production; the Lend-Lease bill of January 1941, passed the following March; and the various war plans in preparation in 1941 for joint participation of American air forces with the British.[16]

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

---

16. ABC-1 plan, 27 March 1941; Atlantic Conference, 11-14 Aug. 1941; A.PD/1, 12 Aug. 1941; and Arcadia Conference, 23 Dec. 1941. AFSHO special study, "Review of Aerial Warfare for the Scientific Advisory Board [Group]," (1945), pp. 15-16, 18.

[redacted]

and if her supposed plans for invading England were wholly or partially successful. In February 1941, for example, General Brett, in submitting about 20 additional developmental projects for General Arnold's approval, warned that the whole Air Corps developmental program had a new element of importance "because" the British program had been "greatly retarded" by the effect of operations on England herself.[17] Similarly, one of the special observers in England early in 1941 (Maj. John G. Moore) was told by Sir Henry Tizard, Director of Research and Development of the British Ministry of Aircraft Production, that "from now on" Anglo-American research and development should be concentrated in the United States, where the activities would be "unhampered by enemy action," and that British technical personnel should be sent "to assist and to pass on such work as satisfying [British] requirements."[18] The Air Corps accepted the pressure of war in England as one more reason for expanding its own research organization. The British proposals to sit in on American research planning and administration were not accepted, however, and became a problem of Anglo-American collaboration that was to vex all parties during the rest of the war long after enemy occupation of England ceased to be an immediate threat.

After America officially entered the war in December 1941 the military requirements for new materiel continued to shift with changes in strategic and tactical plans, including greater emphasis on future

---

17. Memo for Maj. Gen. Arnold by Maj. Gen. George H. Brett, 27 Feb. 1941, in AAG 400.112, Research and Development Programs.
18. Final report to G-2 by Maj. John G. Moore on his visit to Great Britain, 11 April 1941, in Air Intelligence Library, "U. S.-9545."

[redacted]

needs in the Japanese theaters of war. The whole developmental program at Wright Field had grown to about 2,000 different projects by December 1941, "ranging in scope from a complete airplane down to an improved type of cowling."[19] The special Kenney Board was asked in January 1942 to review the airplane development program and to recommend military characteristics for various types, including a 10,000-mile bomber and an "interim" long-range bomber with a range somewhere between the B-29 and the 10,000-mile bomber,[20] a request which indicated the increasing preoccupation with the Japanese theaters of operations. The next month the 1942-1943 program was set up, and included estimates for two jet-propelled fighters (XP-59A's), and for accelerated research with respect to "unconventional" engines, engines in the 4,000-5,500-horsepower class for use in the very-long-range bombers, and controllable bombs and glide torpedoes. The whole story of changing military requirements cannot be treated in detail here,[21] except to note that after December 1941 by far

---

19. Memo for H. H. Bundy, OSW, by Brig. Gen. M. S. Fairchild, Asst. C/AC, 25 Nov. 1941, in AAG 400.112, Research and Development Programs.
20. Memo for Brig. Gen. George C. Kenney, n.d., unsigned, in AAG 360.01, Programs (filed under Jan. 1942).
21. A separate AAF historical study on the Military Requirements System is planned. See also Daily Diaries of Director of Military Requirements, March 1942-March 1943, and of AC/AS, OC&R, April 1943, both filed in AFSHO. Requirements are or will also be treated in some detail in some 20 separate AAF historical studies on specific categories of materiel, such as the Heavy Bomber, Radar and Radio Equipment, Aviation Gasoline and Lubricants, Armament, Bombing Equipment, Reconnaissance Airplanes and Photographic Equipment, and Power Plants, to mention only those in active preparation (as of March 1945). See also ATSC Historical Office "case histories" of selected, specific models of airplanes and equipment (154 currently projected); and the encyclopedic semiannual status report of the ATSC, "Research and Development Projects" (latest ed., 1 Jan. 1945), filed in AFSHO.

[redacted]

the greater impulse came from America's own combat air forces than from the British, and that "theater requirements" came from both the European and Pacific areas, not excluding lesser but important theaters such as the antisubmarine zones in the North and South Atlantic. By early 1944, of the total research and development program of some 1,200 items, the following were regarded as "super projects" by General Arnold and his immediate Air Staff:[22]

Guided missiles

Azon	azimuth-controlled bomb
GB-4	television, radio-controlled glide bomb
GB-8	smoke-flare, television, radio-controlled glide bomb
RTB	radar and television, radio-controlled glide bomb
BQ-2	power-driven, remote-controlled bomb

Airplanes

XB-32, XB-35, XB-36, XB-43 bombers
XP-51F and G, XP-59, XP-72, XP-75, XP-79, XP-80 fighters
Helicopter

Jet engines

General Electric I-16,-20,-40
TG-100
TG-180 and large gas turbine
De Havilland "Halford" H-1
Westinghouse "B"
Aerojet, Aerotojet, Centrojet
Lockheed L-1000
Northrop Turbodyne, Alpha 1500

Conventional engines

Pratt and Whitney R-4360 (for XA-41, XC-99, XP-72, XB-35, XB-36)
Wright R-3350, improved (for B-29 and XB-32)
Allison V-3420 (for XP-75, B-39, B-19A)
Packard V-1650-11 (RM 14SM) (for XP-51G, XP-51H)

---

22. Memo for Brig. Gen. B. M. Chidlaw by Col. R. C. Wilson, both in MM&D, 3 Jan. 1944, listing "super projects" wanted by the Office of C/AS, in M&S file 18.100 Misc.--Gen. The total figure of 1,200 projects is only approximate: in December 1941 it was 2,000; in July 1944, 1,190; while the Materiel Command's "Research and Development Projects" (1 Jan. 1944), though not complete, listed only about 800.

[redacted]

Fuels

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

Computing gun 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 Electric, Sperry "local," and GE 4-gun upper forward turret

B-32 fire control

Sperry A-17 (nose and tail), Martin A-3D (upper), and Sperry A-13 (ball)

20-mm turrets

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

Others

British flame thrower, airborne
Navy rocket, type 3.25

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

As implied in the above sketch, the research and development programs derived from a system of "military requirements" at a higher echelon than Wright Field. During 1939-1941, before American entry into the war, this system was centralized in the Plans Section[23] in the

---

23. 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). The latter offices normally did not formulate either quality or quantity requirements. Occasionally their diaries reveal that they commented on staff studies and R&R's from Requirements or Materiel, and now and then prodded them in behalf of particular projects, such as glide bombs (1942) and rescue equipment (1943).

[redacted]

immediate office of the Chief of the Air Corps, supplemented by a committee usually representing OCAC 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 hoc agencies as the Kilner Board in March 1939 and, later, the Emmons 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.[24]

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 Office of Assistant Chief of Air Staff, Operations, Commitments, and Requirements (AC/AS, OC&R). The exact division of labor between the Requirements project officers and the Materiel project officers occasionally was not clear. The usual stereotyped division of labor, formalized in an OC&R directive addressed to its own requirements officers in April 1943, was that OC&R "formulates and transmits to the Materiel [Command] necessary military requirements . . . upon which . . . Materiel . . . can base its development, production,

---

24. Memo for Chief, MD by Maj. M. E. Gross, 27 June 1940, reporting informal conference of Gen. Arnold, Gen. Brett, Col. Echols, and others on 16 June, in M&S file on R&D Program, F.Y. 1941.

[redacted]

and procurement," while the Materiel Division in M&D "supervises the development, procurement, and production of aircraft, equipment, and supplies . . . [by] the Materiel Command."[25] OC&R officers occasionally went beyond prescribing "what is wanted" to direct "how" the directive was to be carried out by the Materiel organization. Their frequent contacts with project officers at Wright Field, although "informal," occasionally led to contradictory policies being imposed on the latter; and their visits to contractors' plants were occasionally made without direct authorization by Wright Field. These and other deviations from prescribed procedure were not infrequent;[26] apparently they were remedied wherever the staff officers concerned were made aware of them. Maj. Gen. H. A. Craig, AC/AS, OC&R, and Brig. Gen. M. D. Gross, his chief of Requirements, attempted to reconcile informal directness and formal channels by means of an office order in April 1944 on the subject of industrial liaison, that OC&R project officers "will make no commitments, give no instructions, and make no statements to manufacturers which, in any way, might be construed as an approval by this headquarters

---

25. OC&R O.M. No. 9, 22 April 1943, in M&S file 18.100 Misc.--Gen. This directive is similar to the one issued a year earlier, shortly after the Directorate of Military Requirements was established in March 1942. See DMR O.M. No. 9, 17 March 1942, in AAG 300.6, OCAC [sic] Memos, Numbered. See also DMR O.M. No. 12, 23 March 1942, and No. 13, 25 March 1942, both in ibid.
26. For samples of complaints, see memo from Wright Field (Lt. Col. T. A. Sims), 16 March 1942, in AAG 381, War Projects; minutes of Special Directors' Conferences, 19 June, 27 Aug. 1942, in AAG 337, Special Directors' Conferences; M&D Materiel Div. Daily Diary, 20 Jan. 1943, 30 March 1944, 25 Sep. 1944; and memo for Col. J. F. Phillips by R. R. Graichen, both in M&S, 11 Aug. 1944, in M&S file 18.100 Misc.--Gen.

[redacted]

of anything being done by the manufacturers or contemplated by them."[27] In October 1944, when plans for the reorganization of the entire AAF Headquarters were again under consideration, the problem of Materiel versus Requirements was again aired, but apparently neither staff office submitted a drastic recommendation, and the plan called for no reorganization of development and requirements functions.[28] Requirements merely observed that "extreme care is now being exercised to insure that in the future this [interference of Requirements with Materiel's supervision of the development program] will not happen"; and recommended that in some cases AC/AS, Materiel and Services and the Air Technical Service Command be given "more experienced personnel" to make unnecessary the occasional deviations from normal channels by Requirements officers who were more intimately familiar with a given project.[29]

Supplementing the requirements system, but indirectly (through the AAF Board) remaining under CC&R, was the work of the AAF Equipment Board at Orlando, Fla., established about January 1943 in order (among other things) to handle "the problem of liaison with the various theaters, study of different conditions, and the establishing of military characteristics for miscellaneous items of [air] equipment."[30]

---

27. Quoted in minutes of M&D staff meeting, 1 April 1944, in M&D Materiel Div. file of staff meeting minutes.
28. Memo for C/AS by Gen. Arnold, 30 Oct. 1944, in AAG 310.1, Office Administration . . . (filed under 30 Nov. 1944).
29. R&R, Requirements Div., OC&R to AC/AS, OC&R, 17 Nov. 1944, in ibid.
30. Memo for Director of Base Services (Col. L. P. Whitten) by Chief of Staff (Col. B. M. Chidlaw), Materiel Command, 22 Jan. 1943, in M&S file 18.100 Misc. Colonel Chidlaw and Wright Field officers had discussed the work of the new Board with Colonel McGregor, proposed head of the Board.

[redacted]

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 as well.

Ultimately there perhaps was no workable alternative for close collaboration between the planners of research (Requirements) and the supervisors and monitors of research (Materiel), whether the collaboration was to take place in formal committees or in informal day-to-day contact. The committee system, presumably abandoned in 1940, was actually revived from time to time under assumed names. The AAF Materiel Planning Council, set up in July 1942 with members from the directorates and from Materiel Command Headquarters, while it was preoccupied with the fuller "utilization of production capacities," also attempted "to exercise close control over Research and Development,"[31] and for a few months reviewed particularly the modification program by which new and improved devices were being incorporated into existing standard materiel. 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 projects jointly by MM&D and OC&R.[32] By means of formal sessions in 1943 and

---

31. Minutes of Special Directors' Conferences, 7 July 1942, in AAG 337, Special Directors' Conferences. Col. Edmund C. Langmead represented Materiel Command Headquarters.
32. Other staff offices also were represented, including the Deputy Chiefs of the Air Staff and AC/AS, Training. MM&D Materiel Div., Daily Diary, 21 March, 5, 7, 21 April 1944; and correspondence in AAG 380, Programs and Projects (April-May, and Oct. 1944).

[redacted]

1944 representatives of the two staff offices attempted to eliminate projects of marginal value "which are not paying their freight," to regroup priorities in accordance with changing tactical demands, and to provide the "educational" benefit to project officers at all echelons afforded by brief oral descriptions of each project, its status, and its potential value. The review late in 1944 was to be made in accordance with the AAF Materiel Demobilization Plan of 23 September 1944 and "Project B-7" for postwar research, and called for regroupings of priorities as follows: (A) projects which have an intrinsic value for use against Japan; (B) projects which can be completed within 18 months after Germany's surrender; (C) projects of sufficient importance to be classed as "long-range, continuing military developments"; (D) projects in the "suspense category"; and (E) projects which "should be terminated."[33]

The circulation of new ideas or the revival of old ideas useful for application to aerial weapons could not always be rigidly channelized, however, and officers and civilians other than those in the Requirements-Materiel administrative sequence were involved in deviations from this simple organizational pattern. Most prominent were the Air Communications Office (established in December 1941 under a different name),[34] which was concerned particularly with radar, and the special group of "expert civilian consultants," established in April 1942 under Dr. Edward L. Bowles

---

33. AC/AS, M&S Daily Activity Report, 4 Oct. 1944. The "B-7" postwar plan, covering the fiscal years 1946-1950, was prepared about August 1944.
34. See drafts of AAF historical studies on "The Development of Radio and Radar Equipment for Air Operations, 1939-1944" and "Communications Techniques in the AAF, 1939-1945," for discussions on the relationship of ACO to materiel requirements.

[redacted]

to serve both the War Department at large (through the Secretary of War) and the AAF in particular (through General Arnold). Dr. Bowles concerned himself with both developmental and tactical phases of radar, and his group attempted to get the civilian scientist in closer touch with the military strategist, and to forward the thesis that radar and other electronics aids must be recognized in "overall strategic planning in its early stages," instead of leaving the radar scientists and officers "engrossed in the physical devices themselves," on the one hand, and the strategists concerned with their specialties, on the other hand.[35]

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 officially called, was proposed in June 1944, apparently by OC&R, and was intended to represent not only OC&R and M&D but also other Air Staff offices, including the Air Communications Officer and the AC/AS, Intelligence, as well as officials technically outside the Air Staff, such as Dr. Bowles and the President of the AAF Board at Orlando, Fla.[36] 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.[37]

---

35. For a history by Dr. Bowles of his group's activity, see his memorandum for S/W, 23 Aug. 1943, "Resume of Consultant Activity," in AAG 334.7, bulk files.
36. See interoffice correspondence on this Committee, 23-27 June 1944, in AAG 334, Boards . . . Misc.
37. Memo for Committee on AAF Development by AC/AS, OC&R, 6 July 1944, in M&S file, 30.105 New Developments Div. Numerous suggestions for discussion by the Committee, assembled from the various project officers in M&S by Col. R. C. Wilson, July-August 1944 (filed in M&S file, 30.109 Committee on AAF Development), pertain to engines, fuel systems, propellers, armament, guided missiles, photography, and navigation aids.

[redacted]

Its discussions were apparently abandoned by September 1944. Toward the close of the year another committee was established, this time a group of civilian consultants known as the "Scientific Advisory Group," headed by Dr. Theodore von Karman, and attached to the immediate Office of the Chief of Air Staff. As a part of its duties this group was directed:[38]

> to assemble ideas for new weapons, possibly of the "Buck Rogers" variety, for use during this war or for post-war development. Such ideas may be impracticable now, but so long as not opposed to natural laws of science, may demonstrate fields for future research, such as improved explosives, methods of remote control, countermeasures, etc.

One of its studies, in March 1945, concerned long-range, supersonic, rocket-propelled guided missiles of the V-2 type, both winged and wingless.[39]

The ideas and proposals from all these and other sources were in line with General Arnold's demand, voiced in his staff talks on the new Continental Air Forces, that the Air Staff and AAF 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 materiel development, current tactics, and current strategic plans. Ideas from all sources were to be encouraged. Whether, when, and how they were to be translated into changes in "military requirements" and changes in the "research and development program" remained, however, as functions of the staff offices concerned directly with those phases.

---

38. Quoted in minutes of staff meeting of ACO, 19 Feb. 1945, in AFSHO.
39. AC/AS, OC&R Daily Activity Report, 12 March 1945, in AFSHO. OC&R recommended that the Scientific Advisory Group prepare the military characteristics and that M&S prepare a staff study on a change in the administrative responsibility for propellant research, presumably away from the Ordnance Department.

[redacted]

Expansion of NACA Laboratories, 1939-1944

The expansion of the aerodynamic and engine research facilities of the NACA was basic to the prosecution of the Air Corps development programs, and after 1939 there was little resistance by Congress or the press to the financing of NACA activities.[40] The entire budget of the NACA for the five fiscal years 1940-1944 ultimately totaled almost $100,000,000, divided by fiscal years as follows:[41]

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

Distribution of the expenditure of this unprecedented budget, which was about six times the total spent between 1919 and 1939, is shown in the table on the following page.

A large portion of these expenditures went for the new wind tunnels and other laboratory facilities, first at Langley Field, next (1940) at the new Ames Aeronautical Laboratory at Moffett Field, Calif., and finally (1942) at the new Engine Research Laboratory at Cleveland. By 1945 the NACA's $70,000,000 plant contained 30 wind tunnels, including the mammoth 80-foot tunnel for full-scale airplanes at Ames, perhaps

---

40. See Legislation Relating to the AAF Materiel Program, 1939-1944, pp. 102-21.
41. Senate Committee on Military Affairs, The Government's Wartime Research and Development, 1940-44 [Kilgore Committee report, 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, p. 162.

[redacted]

Expenditures by the NACA, Fiscal Years 1939-1944[a]

	1940	1941	1942	1943	1944
Langley Laboratory	$3,857,213	$4,507,864	$ 5,489,939	$ 6,080,398	$14,574,904
Ames Laboratory	2,705,177	2,506,297	6,482,558	4,737,315	4,691,673
Cleveland Laboratory		1,165,868	13,950,208	8,343,068	12,705,263
NACA administration and overhead	203,368	254,903	354,506	391,346	427,035
Funds transferred to universities	25,000	111,921	274,497	344,301	202,455
Funds transferred to Nat. Bureau of Standards	70,000	100,000	100,000	142,300	131,634
Funds transferred to industry		2,791	22,900	49,001	
Total expenditures	$6,860,758	$8,649,644	$26,674,608	$20,087,729	$32,732,964

a. Summarized from financial tabulation in The Kilgore Committee report, The Government's Wartime Research and Development, 1940-44, p. 314. Laboratory figures include construction expenditures.

the largest and most costly piece of scientific appartus in the world; a 1,200-mph supersonic tunnel; and two special tunnels at Cleveland for engine testing--an altitude tunnel and an icing research tunnel.[42] Although there were also many tunnels outside the NACA--27 at engineering schools, 10 at aircraft manufacturers, and 4 each at the AAF and the Navy establishments--none of them was so large, so versatile, and so highly specialized as the equipment of the NACA. Only the federal government could undertake the construction of such equipment and make it available to industry and the military as a "community service."[43]

The NACA's personnel strength likewise grew, from 575 in July 1939 to 1,793 in January 1942 and 6,252 in February 1945.[44] In professional categories, the distribution of employees in 1944 was as follows: 27 per cent, engineers, pilots, physicists, mathematicians, chemists, etc.; 38 per cent, scientific aides, computers, laboratory assistants, draftsmen, mechanics, tool-makers, pattern-makers, etc.; and 35 per cent, clerical and other nonprofessional workers.[45]

The wartime expansion of the NACA normally had the approval and support of the AAF. This support usually took the form of defending

---

42. The NACA also had an "ice research center" at Minneapolis in 1942. (Mentioned in AAG 452.1, Assignment, 6 Oct. 1942.)
43. Several historical sketches on the expansion of the NACA in World War II have been released to the general public: an address by J. F. Victory, Secretary of the NACA, 23 March 1945, in Congressional Record, 79 Cong., 1 Sess., A1568-71 (24 March 1945); George W. Gray, "Trial by Wind Tunnel," in Harpers, April 1945, pp. 446-55; The Government's Wartime Research and Development, 1940-44, pp. 180-84, 314; and "National Advisory Committee for Aeronautics," in Journal of Applied Physics, Aug. 1943, pp. 399-405.
44. Figures from NACA Personnel Office, 28 March 1945.
45. The Government's Wartime Research and Development, 1940-44, p. 181.

[redacted]

NACA budgets before the Bureau of the Budget and Congress, of appealing to the War Production Board (WPB) for preference ratings for materials and equipment wanted by the NACA, of seeking a more liberal draft deferment policy for the younger technical men employed by the NACA, and of supplying the NACA with aviation fuel and lubricants. In some cases, however, the NACA was in competition with the AAF for men and materials, and 100 per cent support by the AAF was denied. Thus, in July 1944 MM&D criticized NACA for seeking White House 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 (in May) the AAF had supported the NACA in getting what it regarded as adequate priorities for the construction of a supersonic wind tunnel.[46] Similarly, in August 1944, M&S (successor to MM&D) entered a nonconcurrence to an NACA proposal seeking 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.[47]

---

46. Minutes of M&S staff meeting, 15 July 1944, in M&S Development Engineering Branch file on "staff meetings"; MM&D Materiel Div., Daily Diary, 31 May 1944; and joint letter to WPB by Gen. H. H. Arnold, Adm. E. J. King, and Gen. G. C. Marshall, 26 May 1944, copy in M&S file 700.280 NACA.
47. Minutes of M&S staff meeting, 26 Aug. 1944, in M&S Development Engineering Branch file on staff meetings.

[redacted]

Expansion of AAF Experimental Facilities, 1939-1944

The tremendous wartime expansion of the research budgets for the AAF between 1939 and 1944 is shown in this tabulation, by fiscal years:[48]

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

These figures are conservative because they exclude general funds such as officer pay, but they do show the trend. Expenditures by the various Wright Field laboratories and by their industrial and other contractors, listed under the three budgetary "projects" of Experimental, Civilian Pay Roll, and Service Test, are shown in the table on the following page.

In terms of civilian and military personnel at Wright Field the following was the situation during the war years 1939-1943 for all materiel activities, both experimental and production:[49]

	Civilians	Officers	Enlisted 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,

---

48. Figures include only amounts obligated by contract with other government, state, and local institutions and with civilian contractors. ATSD and Materiel Command tabulations, covering "projects" 71, 72, and 73 [about April 1944], in WAC file, 700.430 . . . Kilgore Committee, later published by Kilgore Committee, The Government's Wartime Research and Development, 1940-44, p. 305.

49. Materiel Command Historical Office, "History of the Materiel Command, 1926-1941," p. 6a.

[redacted]

[redacted]

AAFHS-50

"Experimental" Expenditures, 1939-1944[a]

	FY 1940	1941	1941 suppl.	1942	1943	1944 (est.)
Chief & Technical Staff	$3,671,155.30	$23,871,902.02	$ 303,398.24	$48,690,505.74	$53,019,598	$34,105,000
Aero-Medical Lab.	2,245.69	2,731.20		71,061.89	129,428	1,400,225
Aircraft Lab.	323,388.69	2,085,174.85	666,630.00	7,357,211.09	3,445,933	3,650,660
Armament Lab.	560,113.22	1,344,086.82		2,061,056.26	3,348,618	3,438,585
Equipment Lab.	257,402.31	2,350,360.29	184,909.53	7,162,649.16	5,560,852	4,911,550
Materials Lab.	14,083.88	41,450.93		59,093.82	102,862	147,150
Photographic Lab.	81,677.34	421,301.94	167,913.64	915,030.07	966,792	425,430
Power Plant Lab.	1,783,386.59	5,173,833.32	61,500.00	8,703,958.25	20,054,793	9,323,645
Propeller Lab.	387,625.87	1,022,746.18		2,077,373.41	1,544,689	2,806,950
Machinery & Lab. Equipment	542,947.07	993,360.14	1,207,638.65	5,186,553.89	3,378,619	2,031,000
Buildings & Grounds	199,331.07	656,255.76	697,027.52	809,634.44	1,214,015	1,195,800
General Engineering	4.70					
General Expense	214,598.07	728,655.44		1,859,282.48	2,977,033	2,119,000
TOTAL	8,037,961.80	38,691,913.89	3,289,017.58	84,953,430.50	95,743,232	65,554,995

Civilian Payroll for Research and Development, 1939-1944

Chief & Technical Staff	$ 69,145	$ 102,535	$	$ 167,933	$ 339,060	$ 368,875
Aero-Medical Lab.			102,000		186,494	218,374
Aircraft Lab.	280,500	389,000		524,730	767,774	959,075
Armament Lab.	118,460	198,460		299,730	443,226	534,131
Engineering Shops Lab.	306,500	427,900		684,530	1,138,340	1,274,832
Equipment Lab.	193,500	254,430		372,890	690,270	843,956
Materials Lab.	135,000	162,900		214,730	263,998	306,904
Photographic Lab.	57,500	78,630		116,730	213,136	262,639
Power Plant Lab.	347,000	494,220		688,130	995,537	1,174,240
Propeller Lab.	95,720	135,250		261,130	506,198	628,563
Technical Data Lab.					385,098	504,621
Machinery & Lab. Equipment						
Buildings & Grounds						
Flight Section					1,063,258	1,091,870
General Expense						
TOTAL	1,603,325	2,243,325	102,000	3,330,533	6,992,409	8,168,110

"Service Test" Expenditures, 1939-1944

Chief & Technical Staff	$	$ 4,703,105.00	$39,830,511.75	$ 3,532,623.50	$ 973,130	$16,391,000
Aero-Medical Lab.					83,695	412,000
Aircraft Lab.	23,339.91	6,786,431.48		181,254.71	703,635	440,000
Armament Lab.	34,336.11	177,125.10		119,466.96	12,623	235,000
Engineering Shops Lab.						
Equipment Lab.	62,648.55	2,303,241.36	2,886.01	571,913.62	540,996	250,000
Materials Lab.	2,269.60	3,060.57		12,500.		50,000
Photographic Lab.	34,820.75	201,514.22		73,589.03	222,772	305,000
Power Plant Lab.	40,871.11	96,583.38	719,043.66	4,958,956.24	6,837,992	925,000
Propeller Lab.	34,914.86	7,716.00		56,677.24	217,008	980,000
TOTAL	233,200.89	14,278,777.11	43,555,441.42	9,506,981.50	9,592,051	19,988,000

a. Tabulation from 1st ind. [Basic unknown], MCD to Director, Budget Div., Office of C/S [about Oct. 1943], in M&S file, 700.430 . . . Kilgore Committee.

revealing 5,976 persons engaged in such activities, divided as follows:

	Civilians	Officers	Enlisted Men
Directors or supervisors	181	268	3
Professional research workers	404	799	56
Laboratory and mechanical assistants	1,494		1,975
Legal, clerical, and others	654	14	128

While only 20 to 25 per cent of the personnel were "directly involved in creative applied research work," all were engaged in "any endeavor leading to the improvement of the quality of production equipment and changes to meet the requirements of the ever changing needs of the theaters of operation." In addition, the Washington office (M&D) included 22 officers and 21 civilians "directly engaged in supervisory control of the Research and Development Program."[50]

Experimental facilities were likewise expanded, perhaps tenfold between 1939 and 1944. In capital investment, Wright Field's plant grew from 10 millions in 1939 to 35 millions in December 1941, and to nearly 54 millions in April 1944,[51] financed partly from the research and development budgets (see p.121) and partly from the separate budgets for construction. The AAF, relatively starved for funds for expansion during the years of peace, prudently seized the war opportunity to build up its permanent facilities for future use against the day when appropriations again might be difficult to obtain. The investment was about

---

50. M&D, "Army Air Forces Research and Development Program," [about April 1944], in M&S file, 700.430 . . . Kilgore Committee.
51. Statement by Brig. Gen. O. P. Echols in Flying, Dec. 1941, p. 83; "AAF R&D Program" [about April 1944], in M&S file, 700.430 . . . Kilgore Committee.

[redacted]

evenly divided between laboratory structures and technical equipment, and was distributed among the various laboratories as follows:[52]

Capital Value of Wright Field Technical Facilities, April 1944

Laboratory	Laboratory Structures	Technical Equipment	Total
Aero Medical	$ 270,000	$ 200,000	$ 470,000
Aircraft	6,100,000	5,100,000	11,200,000
Aircraft Radio	2,000,000	6,140,000	8,140,000
Armament	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	5,550,000
Materials	700,000	600,000	1,300,000
Photographic	200,000	600,000	800,000
Power Plant	6,100,000	7,200,000	13,300,000
Propeller	2,400,000	2,200,000	4,600,000
Technical Data	300,000	400,000	700,000
	$28,470,000	$25,770,000	$54,240,000

Among the outstanding facilities were the following, spread across the changing map of Wright Field:[53]

Aircraft Laboratory

Wing tunnels (both vertical and horizontal, for tests at various simulated altitudes and at supersonic speeds)

52. Ibid.
53. Ibid. See also "Master Plan" of Wright Field, in files of M&S Air Installations Div.; and various aerial photographs of Wright Field during the years 1926-1943, in Materiel Command Historical Office, "History of the Materiel Command, 1926-1941," Appendix.

[redacted]

Aircraft Laboratory (cont'd) [redacted]

Structures test equipment
Design and mock-up facilities for scale construction
Engineering, vibration, and other equipment to determine suitability of aerodynamic, structural, vibration, and flutter characteristics

Aero-Medical Laboratory

Altitude chambers
All-weather room
Centrifuge equipment
Animal-research quarters

Armament Laboratory

Armament firing and calibration rooms
Gun ranges
Altitude 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
Cold room
X-ray room

Power Plant Laboratory

Engine test stands
Jet propulsion test stand
Dynamometers
Fuel test equipment
Torque stands
Supercharging room
Calibration room
Altitude equipment
Cold and tropical weather rooms

Photographic Laboratory

Dark rooms
Camera workshops
Cold room

[redacted]

Propeller Laboratory

Propeller test whirl rigs
Torque stands
Vibration rooms

Outside of Wright Field were several additional facilities under the jurisdiction of the same command, including the experimental flight test site at Muroc Dry Lake, Calif., established in 1941; the glider test field at Wilmington, Ohio, about 1942; racks for "exposure durability tests" of coatings, plastics, and other materials at the Homestead Air Base, Fla., about 1943; and the rocket test base at Dover, Del., in 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,[54] General Marshall approved the transfer of airborne radio and radar activities to the AAF, stating that he was "increasingly impressed" that "the design and operation of aircraft is becoming more and more inseparably associated with radio and radar development," and that the latter must be "treated . . . as a part of the main problem of aircraft design and operation rather than as accessories."[55] In

---

54. The long history of Air Corps-Signal Corps relations cannot be recited here. For a brief discussion, see draft AAF historical study, "The Development of Radio and Radar Equipment for Air Operations, 1939-1944."
55. Memo for Gens Arnold (AAF) and Somervell (ASF) by C/S, 26 July 1944, photostat in M&S file, 30.105 New Developments Div.

[redacted]

this shift the AAF inherited the Signal Corps facilities at Wright Field (chiefly the Aircraft Radio Laboratory, built up over many years adjacent to the Air Corps laboratories), together with an estimated 195 officers, 170 enlisted men, and 1,470 civilians; the field laboratories at Boca Raton and Florosa, Fla., and Indianapolis, Ind.; and a field station at Clermont, Fla.[56] Further expansion was planned by the AAF after the transfer was effected in October 1944. The research and development budget estimates for radio and radar work were expanded, and additional facilities were foreseen. In this direction, M&S 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.[57]

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 had a portion of its budget allotted to remote-control bombs, and in about October 1941 General Arnold had directed an expansion of the air base at Muroc Dry Lake, Calif., including the assignment of a permanent detachment there for the testing of glide bombs, the "aerial torpedo," and controlled wing bombs.[58] The materiel organization, and the AAF as

---

56. Ibid.
57. AC/AS, OC&R Daily Activity Report, 8-9 April 1945.
58. Brig. Gen. O. P. Echols, Chief of the Materiel Div., had expressed doubt that there would be "enough testing there [at Muroc] to warrant a special detachment." (Quoted in transcript of telephone conversation, Brig. Gen. Carl Spaatz to Brig. Gen. M. S. Fairchild, 4 Nov. 1941, in AAG 311.3, Telephone Conversations for Gen. Spaatz [bulk files].)

[redacted]

a whole, were preoccupied with other more urgent development projects in 1942 and 1943. At the same time, the Muroc test site was expanded and a number of projects were under way both in the AAF and the Signal Corps. Materiel officers were aware, like the Chief of the Armament Section in Washington in March 1943, that it was "unwise . . . from both the technical and political angle . . . to inadequately recognize the possibilities that lie in developments of this nature."[59] In June 1944 guided-missiles development was given a new impetus by the spectacular use of robot bombs by the Germans, together with a growing interest in guided missiles on the part of the senior air commanders overseas. The expansion of the Special Weapons Unit at Wright Field was approved by General Arnold on 11 July, calling for about 250 extra personnel and additional construction at Wright Field and at the Muroc Air Base; and in September, military characteristics for various new missiles were established as the basis for the future development program.[60]

Involved also was the problem of whether the AAF would achieve full jurisdiction over the program, in both its tactical and materiel phases.

---

59. Memo for AC/S-E, Materiel Command by Col. M. H. Joiner, 8 March 1943, in AAG 380, Programs and Projects. Joiner urged more collaboration with the Naval Research Laboratory, the NDRC Radiation Laboratory, and three firms--Fairchild, Douglas, and Interstate.
60. M&D Materiel Div., Daily Diary, 26, 30 June, 10, 12 July 1944; memo for C/AS by M&D [about 11 July 1944], in AAG 380, Programs and Projects; and memo for Ordnance Dept. by C/AS (written by Col. F. H. Richardson, M&S), 7 Sep. 1944, in AAG 360.2, Development and Research.

[redacted]

The Army Ground Forces, Army Service Forces (ASF), and Ordnance all were interested in controlling development of those missiles that were "ground launched"; the AAF was interested not only in "aerodynamic" missiles but also in any that were to be used in strategic bombing; and the Signal Corps was involved, since most of the missiles would use radio or radar controls. The problem of the Signal Corps was settled when its entire air-related responsibilities were shifted to the AAF in August. The air-versus-ground controversy was arbitrated by the General Staff in September 1944, as follows: The AAF was to develop all air-launched missiles and all aerodynamic missiles, regardless of how launched; the ASF was to develop all ground-launched "momentum" missiles, with military characteristics coordinated by Army Ground Forces. In either case, "ultimate tactical employment" was not to be determined exclusively until development progressed further. This division of responsibility applied likewise to the development of propulsion units (ram-jets, rockets, or "more conventional means") and control systems (mechanical, radio, radar, television, or infra-red); but war heads, non-integral launching devices, ground components of control systems would each be handled by that Army procurement service that had "the basic technical ability in research," presumably the Ordnance Department and the Signal Corps.[61] It was a "compromise" agreement between tactical commands and between procurement services,

---

61. AC/AS, P&S Daily Activity Report, 14, 19 Sep., 10, 15 Oct. 1944.

[redacted]

according to the Chief of the OC&R, Requirements Division:[62]

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

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 GHQ Air Force), a modification of the general theory that final evaluation of a product and its tactical application should be out of the hands of those who had engineered or supervised the development. During the two decades of peace (1920-1940) this activity, on a very small scale, was located at Wilbur Wright Field, Ohio (renamed Patterson Field in 1931), and in the very early years (about 1918-1921) included Maj. R. W. Schroeder's "testing and proving squadron." In 1937, the GHQ Air Force 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 engineering facilities at [near-by] Wright Field and the repair facilities at Patterson Field, and . . . permit the engineers at [both] Fields to be in constant touch with the tests.[63] The testing activities continued

---

62. Disposition slip, Brig. Gen. H. E. Gross to Col. S. F. Giffin, 13 Sep. 1944, in M&S file, 30.105 New Developments Div.
63. Recommendation of the Bryden Board, 22 July 1936, in AG 400 (4-6-36), sec. 1. For GHQAF Progress Reports on service tests, 1938-Aug. 1940, see AAG 400.112, Status of Service Tests Being Conducted by GHQAF, Special File. See also AAG 400.112, Fairfield Service Tests (March 1921-Sep. 1942).

[redacted]

into 1941, under the reorganized Air Force Combat Command, and the test detachments normally consisted of two combat crews per airplane.[64]

Meanwhile in the fall of 1939 the armament phases of service testing began to be shifted to Eglin Field, Fla., and control shifted from the GHQ Air Force to the Air Corps Board and its recently organized 23d Composite Group.[65] 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, Ohio, Aberdeen Proving Ground, Md., Oscoda, Mich., and others. By November 1939 the 23d Composite Group was conducting its first armament tests there, involving the P-36D and P-36E and the XP-37; and in August 1940 it began its first bombardment tests. Only armament and air ordnance tests were under consideration when the site was originally selected, and even as late as May 1941, when Eglin Field and the 23d Composite Group were reorganized into the "Air Corps Proving Ground," the new directive defined the testing mission only in terms of "tactical tests of aircraft armament and

---

64. Memo for C/AAF by C/AC, 25 July 1941, in AAG 400.112, Tests and Experiments (filed under 11 Sep. 1941). Exactly when service testing at Patterson Field was abandoned is not known. Various proposals were made for retaining the work there, including a plan by J. N. Fiala of the Materiel Division in August 1940. See R&R, Chief, MD to Plans, 10 Aug. 1940, in AAG 400.112, Tests and Experiments.

65. The discussion in this and following paragraphs is summarized, except where otherwise noted, from data selected from Proving Ground Command Historical Branch, "Historical Outline of the Proving Ground Command," especially pt. 1, pp. v, viii, 16, 20, 23, 31-32, 40, 64-65; and pt. 2, Appendix A, Exhibits 5, 6.

[redacted]

its accessory equipment."[66] Furthermore, the appointment of one of the Materiel Division's top-ranking armament officers (Col. Grandison Gardner) to head the organization in 1941 emphasized Eglin Field's armament mission; and in general there was an awareness in the Air Corps that armament was the biggest gap in the testing program.[67]

At the same time, however, ever since November 1939, the 23d Composite Group had undertaken some nonarmament tests, and by the end of 1941 more than half of its projects were outside the field of armament.[68] Ultimately the more inclusive function covering all air materiel was acknowledged when the Air Corps Proving Ground was reorganized into an AAF command in April 1942. More than half of the nearly 1,500 test projects undertaken at Eglin Field between late 1939 and

---

66. Directive of 26 May 1941, in PGC Historical Branch, "Historical Outline," Jan. 1945, pp. 39-40. Similarly on 15 September 1941 the Air Corps Board issued a 16-page "Program of Accelerated Service Tests of Aircraft Armament and Accessory Equipment" (copy in AFSHO and in AAG 400.112, Test, Development Work).
67. 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 (presumably on the basis of his observations in England) an "Aircraft Armament Proving Ground" devoted "solely" to that specialty, "entirely divorced from other activities," and manned by Air Corps and Ordnance personnel. See Moore's final report to G-2, 11 April 1941, in Air Intelligence Library, U. S.--9545. The Materiel Division (Lt. Col. F. O. Carroll, Chief of [redacted]) likewise dealt entirely with armament in "urging" such a Proving Ground in a study on 24 April 1941; and the Air Force Combat Command (Brig. Gen. C. [redacted] Russell) concurred in the proposal on 12 July 1941. See Hq. Materiel Command file on CTI-190.
68. Most of the 23d Composite Group's test reports, progress reports, and related correspondence of OCAC headquarters in 1940 are filed in AAG 400.112, Test, Development Work, and in AAG 400.112, bulk files.

[redacted]

February 1945 were concerned with the operational suitability of aircraft and of air equipment other than armament and ordnance.[69]

The wartime expansion of facilities for "operational suitability" tests at Eglin Field was comparable in extent to the expansion at Wright Field.[70] In October 1940 the field itself was vastly enlarged by the acquisition of the Choctawhatchee National Forest adjoining Eglin Field, followed by the construction of special runways and several auxiliary fields and the building of special hangars, laboratories, and administrative buildings on the reservation. Allotments to undertake this construction were as follows, by calendar years:

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

In addition to its facilities at Eglin Field,[71] the Proving Ground

---

69. See Proving Ground Command Historical Branch, "Index and List of Service Tests Activated at Eglin Field (1939-28 Feb. 1945)," 2 vols., in AFSHO. This valuable reference manual is a cumulative historical list of all PGC tests on airplanes and other materiel, 1939-1945, showing test number, title of test, and completion date or other disposition. It is arranged according to category of materiel or operational techniques, and is supplemented by an exhaustive analytical index to specific materiel nomenclature, cooperating or other related agencies (e.g. Materiel Command, Navy, NDRC, the British, manufacturers), and some tactical and other subjects.
70. A separate historical study on the facilities of the Proving Ground Command is in preparation by the PGC Historical Branch.
71. See also "Tentative Program for Master Plan [of facilities] of Eglin Field," 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," Appendix A (Exhibit 63), Appendix D (Figure 13), and Appendix C, passim.

[redacted]

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

Still another group of service testing facilities established during the war were those belonging to the tactical development organizations set up at Orlando, Fla., beginning in 1942.[72] The Air Defense Board (about March 1942) and the School of Applied Tactics (November 1942), reorganized in October 1943 as the Tactical Center,[73] were all concerned primarily with developing tactical doctrines for the employment of aircraft and air weapons, but the operational testing of specific equipment was inevitable if operational doctrines were to be formulated effectively. While "materiel tests" at Orlando were not specifically authorized by any formal directive until June 1944,[74] a large number of the projects were on the performance of equipment, chiefly equipment procured by Army supply services other than the AAF[75] such as the Signal Corps, the Quartermaster Corps, and the Corps of Engineers. A notable

---

72. See draft AAF historical study, "The Development of Tactics in the AAF"; and histories of the AAF Board and the Tactical Center, in preparation.
73. AAF Regs. 20-14, 12 Nov. 1942; 20-14A, 22 Dec. 1942; 20-14B, 26 Feb. 1943; 20-14, 2 July 1943; 20-14, 8 Oct. 1943; 20-14A, 12 Nov. 1943; 20-14A, 30 March 1944; and 20-14, 5 June 1944.
74. AAF Reg. 20-14, 5 June 1944.
75. AAF Reg. 20-14, 21June 1944.

[redacted]

early example of this activity was the work of the Air Defense Board and the Fighter Command School at Orlando in July and August 1942, in testing experimental models of a light-weight aircraft warning and fighter control system, intended for use in the North African landings that were to occur the following November.[76]

The testing activities at Orlando, together with the operational suitability tests at Eglin Field, were all controlled by the AAF Board in terms of jurisdiction between testing fields and priorities among projects; and the AAF Board was in turn subject to the staff supervision of OC&R in Washington.[77] Duplication and overlapping between Eglin Field and Orlando were thus made more preventable; a further step in this direction was to place both of them under a newly designated "AAF Center" on 1 June 1945.

The relation of these two testing establishments, however, to the Flight Test Section and other test activities of the Materiel Command was not so clear. To remedy this, one of the elements of the plan for an Initial Postwar Air Force, under consideration in April 1944, proposed that Wright Field's flight testing be merged into the Proving Ground Command. M&D doubted that such a shift would "contribute to rapid and effective test" and proposed instead that the Flight Test Section be established as a separate command coordinate with the

---

76. Draft AAF historical study, "The Development of Tactics in the AAF," pp. 40-42, 52-53.
77. AAF Reg. 20-20, 26 April 1944.

[redacted]

Proving Ground Command; that both be assigned as subordinate commands under Materiel jurisdiction;[78] and that the flight test organization, the facilities of which were admittedly "inadequate," be "strengthened" and perhaps moved to a "new base specifically for flight testing."[79] In the proposed AAF reorganization in October 1944, no disposition of the problem was made.

The AAF and Cooperative Research, 1940-1944

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

Ordnance Department: bombs, rockets, guns, and ammunition, as well as ground-force ordnance;
Chemical Warfare Service: special ordnance such as incendiary bombs, as well as ground-force items;

---

78. Memo for Chief, MD by Col. R. C. Wilson, 15 April 1944, in M&S file, 18.100 Misc.-Gen.
79. Memo for Maj. Gen. O. P. Echols by Col. J. F. Phillips, 3 July 1944, in M&S file, 30.109 Committee on AAF Development.

[redacted]

Signal Corps: radio and radar equipment, both air force and ground force items until the transfer of air-related development to the AAF in October 1944;
Corps of Engineers: airfield construction equipment, crash trucks, etc., as well as ground force items;
Quartermaster Corps: air rations, flying clothing, and other special personal equipment, as well as ground force items and items common to the entire Army.

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

AAF	$418,755,020
NACA	95,005,703
OSRD (including NDRC)	347,855,830
Signal Corps	168,808,378
Ordnance Department (Army)	172,775,914
Chemical Warfare Service	20,391,720
Corps of Engineers	34,612,072
Quartermaster Corps	2,946,586
Navy Bureau of Aeronautics	171,335,326
Navy Bureau of Ordnance	109,067,894
National Bureau of Standards	31,117,000
Civil Aeronautics Administration	3,247,628

The research expenditures of most of these agencies covered more than air materiel 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, such as the Forest Products Laboratory of the Department of Agriculture, contributed to the solution of AAF problems. 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 on wartime research in the physical sciences, compared to only $250,000,000 spent in 1939 by federal and private agencies for both war and peacetime

[redacted]

research. While this expansion does not necessarily demonstrate that the utilization of the nation's scientific resources was complete or "total," it nevertheless gives some indication of the conversion of the scientific resources from peacetime pursuits to the development of weapons and other 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 the agency's own research activities, is roughly shown in the tabulation of expenditures by each agency on the following page.

In the vast government-industry-university cooperative enterprise suggested in the above statistics, the one new element in World War II experimental activities was the work sponsored by the National Defense Research Committee; all the other agencies were peacetime establishments expanded to a war basis. The NDRC[80] was established in June 1940 with White House approval as an emergency agency to "correlate and support scientific research on the mechanisms and devices of warfare" and to "aid and supplement the experimental and research activities of the War and Navy Departments."[81] The wording of this directive thus acknowledged

---

80. Except as otherwise noted later, the source for statements on the NDRC is ibid., pp. 216-26.
81. Council of National Defense order, 27 June 1940, in Federal Register, 2 July 1940, p. 2446.

[redacted]

Total Expenditures for Wartime Research and Development, 1939-1944[a]

Agency	Total research	Within establishment	On industry contracts	On university contracts
Army Air Forces	418,755,020	53,759,308	337,448,692	2,453,659
NACA	95,005,703	91,797,745	74,692	958,174
OSRD (including NDRC)	347,855,830	none	110,046,850	220,816,521
Signal Corps	168,808,378	72,739,268	57,998,336	321,455
Ordnance Department	172,775,914	43,293,132	116,281,839	none
Chemical Warfare Service	20,391,720	16,544,741	2,834,820	none
Corps of Engineers	34,612,072	8,391,821	9,079,308	none
Quartermaster Corps	2,946,586	2,491,513	none	134,580
Bureau of Aeronautics (Navy)	171,335,326	6,329,000	160,334,820	197,000
Bureau of Ordnance (Navy)	109,067,894	none	34,369,779	697,171
National Bureau of Standards	31,117,000	28,452,200	none	29,500
Civil Aeronautics Administration	3,247,628	886,148	489,148	205,800

a. Kilgore Committee report, The Government's Wartime Research and Development, 1940-1944, pp. 302-04, 306, 308-10, 314, 323. In addition to the last three columns, which represent expenditures for actual research, are the expenditures for administrative overhead within each agency (sometimes segregated), and funds transferred to other federal agencies or to state and local governments. For detailed breakdown by all these types of expenditures and by fiscal year, see ibid., pp. 282-323.

the network of existing Army and Navy facilties both to conduct independent research and to guide, review, and test the research done for the services by industry and other nonmilitary scientists; but at the same time implied that the utilization of industrial and university research facilities was far from complete. The origins of the NDRC can probably be traced to civilian scientists outside the Army (chiefly Bush, Compton, and Conant) rather than to any of the military agencies. In fact the Air Corps, and probably other supply services of the Army as well, two months earlier had opposed a plan for a similar organization, the Air Corps arguing that the existing coordinating bodies were "adequate" and that it preferred "direct" collaboration with industry and the universities.[82] One factor in this skeptical attitude was the traditional direct relationship between the aircraft industry and military aeronautics, a more intimate civil-military relationship than that existing between industry and either the ground or naval arms. The Air Corps, together with the NACA, by 1940 had already gone farther toward scientific mobilization than any other arm. This special air situation was recognized in the NDRC directive (quoted above), which specifically excluded the NACA and its "problems of flight" (aerodynamics, structures, and propulsion) from the work of the new committee.

Once the NDRC was established, Air Corps headquarters saw in the new agency an opportunity to pursue scientific research on a number of non-aeronautical problems whose solutions were vital to the fullest

---

82. 1st ind. (AG 381 "National Defense" (3-11-40), 14 March 1940), C/AC to TAG, 11 April 1940, in AAG 400.112, Test, Development Work.

[redacted]

effectiveness of air operations. Coincidentally, in June 1940 the Air Corps' own experimental program was suffering from the frantic demands for quantity production. General Arnold "assured" the Chief of Staff that the research and development program would be deferred, and suggested that some phases of it might be transferred to "some other governmental agency," presumably referring to the new NDRC. Shortly thereafter a number of scientific problems were submitted to the NDRC by the Air Corps: five of them in July and 20 in August, including the baffling question of bombing-through-overcast.[83] Maj. B. W. Chidlaw, the newly appointed NDRC liaison officer in the Air Corps, in submitting these problems, recognized that some of them were "abstract," but acknowledged that the NDRC might be able to "disclose immediately likely lines or phases of investigations overlooked by . . . the Experimental Engineering Section, . . . Materiel Division." He further invited the NDRC scientists to visit Wright Field laboratories "at any time" and promised them the Materiel Division's "wholehearted cooperation."

Wright Field officers in 1940 were skeptical, and it was some months before NDRC projects were accepted as a normal phase of the Air Corps experimental program. Maj. F. O. Carroll and Capt. H. Z. Bogert suspected that NDRC projects would cause "considerable duplication of the work already under way with the National Advisory Committee for Aeronautics, the National Bureau of Standards, and the National Academy of Sciences"; doubted that the NDRC "can do any more than is already being done by

---

83. Maj. B. W. Chidlaw to Dr. Vannevar Bush, NDRC, 22 July 1940 and 28 Aug. 1940, and OTI-113, 18 Oct. 1940, all in AAG 400.112, Test, Development Work. Some of these projects were later shifted to the NACA.

[redacted]

existing coordinating bodies"; and predicted that "most of the work will finally wind up at Wright Field and that [meanwhile the NDRC] . . . 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."[84] When NDRC 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."[85] Furthermore, one NDRC activity, the microwave radar work at the Massachusetts Institute of Technology, was already showing results. Major Chidlaw observed that it was "moving along in high gear and . . . obtaining results and equipment far beyond that which might normally have been expected had the Air Corps and Signal Corps been forced to handle this through regular development channels."[86] Skepticism ultimately disappeared within the Air Corps. Instead of complaints that NDRC scientists were taking the time of Wright Field officers, Air Corps complaints arose in the other direction, that NDRC officials did not visit Wright Field enough, that they were inclined to remain in Washington and "coordinate" at long distance.[87] The

---

84. Memo for Technical Exec., MD by Maj. F. O. Carroll, 2 Nov. 1940, in AAG 400.112, NDRC (filed under 25 Nov. 1940).
85. Memo for Technical Exec., MF by Lai. E. L. Powers, MD, 25 Nov. 1940, in ibid.
86. Memo for Col. O. P. Echols by Maj. B. W. Chidlaw, 14 Dec. 1940, in ibid.
87. Interview with Maj. Gen. O. P. Echols, 11 May 1945.

[redacted]

dependence of the AAF on the NDRC for certain of its nonaeronautical research became so great that in September 1944 the AAF protested at the "premature" NDRC plans for demobilizing 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 program] . . . until the defeat of Japan," and by the end of 1944 prepared to take over the more "promising" projects that the NDRC had sponsored.[83]

The NDRC was a new agency in World War II, but not all of its procedures were new. In fact some of them were not different from the Army's: the NDRC negotiated contracts with universities and industrial firms, much as the Army did; it monitored the progress of the research, and kept higher echelons informed, just as the Army supply branches and materiel 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 NDRC had no laboratories of its own for conducting independent research or for testing the results of its contractors; and NDRC's contracts 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 temporarily recruited from private positions (437 of them were not salaried, as of spring 1944), whereas the Army's experimental establishments (for example, Wright Field)

---

88. M&S Materiel Div., Daily Diary, 2 Aug., 12, 21 Sep. 1944; and M&S Daily Activity Report, 9 Sep. 1944, all in AFHRO.

[redacted]

were composed of permanent personnel, both military and civilian, as well as some Reserve officers temporarily in the Army, many of them distinguished in fields of aeronautical engineering and most of them comparing favorably with the equivalent technical personnel in industrial and academic institutions. The chief contribution of the 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 1941,[89] and the impetus of additional scientists, chiefly in universities, many of whom were not accustomed to dealing with the Army until they were mobilized by NDRC officials who "spoke the same language." Once the specific scientific projects were established by the NDRC and properly allocated among the available universities and firms, the AAF and other Army branches concerned assigned liaison officers or project officers to follow the projects, and the services received regular progress reports on each project. Most of these projects, totaling 978 for the period from June 1940 to March 1944, represented problems submitted by the Army and Navy rather than projects undertaken independently by the NDRC. Of these projects, about 125 were sponsored by the AAF, and 500 by the other supply services of the Army Service Forces, the latter including of course many of primary interest to the AAF. By December 1944 the Army's active projects with the NDRC totaled 299, including 79 for the AAF and 220 for the ASF, the

89. The NDRC was supported entirely by White House funds in the F.Y. 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 (233.1 millions), the War Department (50 millions), the Navy Department (54.4 millions), and the Lend-Lease Administration (4.5 millions).

[redacted]

latter including 32 sponsored by the Signal Corps for the AAF before the Signal Corps air functions were transferred (in October 1944) to the AAF.[90]

Among the other research agencies was the Navy Bureau of Aeronautics, which had its experimental establishments at Philadelphia, Pa., and Patuxent, Md., providing still another source of research and development for the AAF. Unlike the ASF and the NDRC, the Navy's relationship toward the AAF was, of course, competitive. Both the AAF and Navy materiel centers were developing many items of aircraft, engines, armament, bombing equipment, and other apparatus that were similar if not identical as to tactical requirements and uses. Aside from the Navy's special equipment for carrier-based aircraft, most of its equipment was, after all, common to military and naval aeronautics. Obviously there was duplication of effort between them, in spite of the occasional assertions to the contrary by either or both of the arms. The responsible AAF officers usually denied, not that there was duplication, but that there was "unnecessary" duplication of effort,[91] and the two research and development programs were frequently rationalized as a desirable situation of "parallel development" not unlike the independent research conducted by two or more scientists on the same idea, or the independent design of a bomber by two firms (for example, the Boeing B-17 and the Consolidated B-24). The "bogey of duplication" in scientific matters, the allegation that the "duplication of equipment and effort is in itself

---

90. M&R, ID to M&S, 5 Dec. 1944, in AAG 334, Boards . . . Misc.
91. M&R, Supply Division to Col. Carl Spaatz, 29 July 1939, in AAG 400.112, Tests and Experiments.

[redacted]

evil and wasteful," was attacked by Col. Carl F. Greene, the AAF liaison officer at the NACA, as follows: "Almost all [scientific] findings, concepts, and opinions . . . are controversial"; two or more laboratories "may well contribute to the wholesome and necessary process . . . of checking and questioning the teachings of the original investigators"; and the "right of research agencies to scrutinize and disagree with each other's work is as valuable in achieving scientific progress as is freedom of speech informing public opinion."[92] Whether this theory was also a fact, as between the Army and the Navy, cannot be definitively evaluated here without specific analysis of the history of the various materiel projects involved, successful and unsuccessful. One estimate by the Bureau of Aeronautics, in February 1942, could cite only three materiel developments that had resulted from such divided air forces: the aircraft-launched torpedo (Navy), the dive bomber (Navy), and the heavy and medium bombers (Army) were cited as examples of "progress that might not have been realized from a single air force."[93]

Whatever the merit of these claims (and each of the specific examples might be debated), the two experimental establishments did not actually work entirely independently of each other. Joint consultation between them was common, including periodic reviews of their research and development programs, in 1939 as in 1944; joint conferences in NACA committee deliberations, a standard procedure that dated back

---

92. Memo by Greene, 30 June 1944, in AAG 360.2, Development and Research, filed under 11 July 1944.
93. Memo for C/AAF by Rear Admiral J. H. Towers, Bu. Aer., 14 Feb. 1942, in AAG 452.1, Production of Aircraft.

[redacted]

to the very beginnings of the NACA in 1915; and the system of liaison officers exchanged by the two materiel centers, a practice that apparently began in 1939.[94] The Navy was probably more aggressive than the AAF in pursuing this liaison. Thus, the AAF had only a single full-time officer with the Bureau of Aeronautics (Col. John H. Sams); and while his reports on Navy developments were frequent and informative,[95] WADD and Wright Field were "frequently . . . criticized for lack of liaison," especially at Navy tests at locations other than Philadelphia and Patuxent.[96] The Navy, on the other hand, carefully attended most AAF mock-up inspections and tests; stationed over a dozen permanent officers at practically all of the laboratories and units at Wright Field, provoking one comment that every AAF project officer had a Navy officer "breathing down his neck"; and in August 1944 took steps to copy the plans and drawings of many of Wright Field's test facilities for use in expanding its own naval air materiel center.[97]

The AAF was opposed to formalizing this collaboration with the Navy to the extent of throwing its research and development program together with the Navy's into a committee that might tend to remove the AAF from direct control over its own materiel activities. Thus in 1940 when the Navy suggested that very procedure--a proposed joint subcommittee

---

94. See OCAC O.M. 10-4, 14 June 1939, in AAG 300.6, OCAC Memos, Numbered.
95. WADD Materiel Div., Daily Diary, 2 June 1944, in AFSHO.
96. Some of Col. Sams' reports are in AAG 380, Programs and Projects (20 May, 20 June, 24 Nov. 1944), 360.2, Development and Research (12 Oct. 1944), and 000.71, Interviews (30 Sep. 1944).
97. Memo for Chief, Engineering Div., by Bu. Aer. General representative at AF, 23 Aug. 1944, in AFDO 045.2, Navy.

[redacted]

of the NACA--it was scolded by the Air Corps for abdicating, in effect, its basic responsibility for military requirements and tactical evaluations: the Army and Navy "should [not] admit that the pressure of business makes it necessary to transfer to a third agency [the job of] coordination between us"; the existing Army-Navy liaison system "can keep the two programs integrated without outside non-military help." It was Air Corps opinion that it was the tactical requirements, known only to the Army and the Navy, rather than technical limitations or scientific frontiers (the province of the NACA) that must determine the projects and priorities of the research and development programs; and, finally, that the Navy proposal "would place in the hands of the NACA a control over naval and military experimentation never intended by the acts establishing and empowering the NACA with aviation experimental authority [and] . . . not . . . to the best interests of our two services."[98]

Nor was any other permanent or ad hoc wartime committee appointed to control the Army and Navy air programs for research and development. The Joint Chiefs of Staff, established late in 1941, did not assume jurisdiction. They did, however, set up a Committee on New Weapons and Equipment in 1943, but it was more a device to bring the civilian head of the NDRC (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 apparently did not seriously affect the direction or emphasis of the AAF program.

---

98. Memo for Rear Admiral J. H. Towers, Bu. Aer., 25 Oct. 1940 (draft), in AAG 400.112, Tests and Experiments.

[redacted]

Within the War Department, the AAF's growing autonomy after 1939 had repercussions on its research and development program. The General Staff, which had earlier in the past two decades adversely affected (for example) the development of the heavy bomber, had no appreciable influence on the development program after 1939. G-4 had no representation on the Milner Board in 1939, and only a junior officer on the Lemons 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 materiel; and in September a directive reminded the supply services that the Chief of Staff and his deputy were responsible for "the coordination of the functioning of [research and development] agencies" throughout the War Department.[99] The correspondence and other records of G-4, however, reveal little concern or interference with the AAF program by higher authority after 1940.[100] Soon General Arnold, Chief of the Air Corps, became Deputy Chief of Staff for Air, a move that was symptomatic of this growing autonomy. Thus, in February 1941, when the Secretary of the General Staff sought to review the Air Corps research and development program by asking for comprehensive data on Wright Field projects, General Arnold halted the review with the query, "Since when did the Air Corps cease to be a part of the War Department?" and Maj. Gen. G. H. Brett, the new Chief of the Air Corps, ordered the Materiel Division to "file away and forget" the General

---

99. AG 320.2 (7-29-40), 6 Aug. 1940, "Defense Projects," in AAG 380-381-381.4, National Defense; and AG 320.2 (9-10-40), 14 Sep. 1940, "Coordination of Research and Development . . .," in AAG 400.112, Tests and Experiments.

100. See G-4 case files, and index to them, 1921-43, in AGO War Dept. Records Branch.

[redacted]

Staff request.[101] The budget section of the General Staff likewise tended to lose its policy-making functions with respect to the AAF; in July 1941 the Materiel Division was able to prepare its research and development budget independently of "the long drawn out rigmarole of coordination with the General Staff."[102] After 1941, the budgets 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,[103] essentially the reappearance of the research and development section of G-4. Its directive was worded in very comprehensive and all-inclusive terms: "the innovation, development, and application of new weapons, devices, and techniques of military value," subdivided into eight large functions apparently covering every phase of planning, supervision, and control.[104] 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.

---

101. AG 400.114 (1-13-41), 5 Feb. 1941; memo for Col. Orlando Ward, Sec. of AMC, by Maj. Gen. H. H. Arnold, 11 Feb. 1941; and notation by Brett to Brig. Gen. C. P. Echols, 19 Feb. 1941, all in M&S Development Engineering Branch file on M-D Program, F.Y. 1941.
102. Inter-desk memo, Lt. Col. B. M. Chidlaw to Brig. Gen. C. P. Echols, 8 July 1941, in M&S Development Engineering Branch file on M-D Program, F.Y. 1942.
103. AAF Circular 333, 15 Aug. 1943.
104. Memo for Director, NDD by S/W, 13 Oct. 1943, copy in M&S Development Engineering Branch file, 30.105 NDD; and AAF General Council, Minutes, 22 Feb. 1943, p. 1, 25 Oct. 1943, p. 1 and Enclosure "A," and 1 Nov. 1943, p. 8, all in AAG 337, Conferences, bulk files.

[redacted]

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

Within the War Production Board, for example, there arose in June 1942 a proposal for a WPB Office of Technological Development, to "utilize the scientific resources of the country . . . and to investigate new processes, devices, and ideas," all "in coordination with" other government agencies. No AAF representatives were present at the hearings on the proposal, but objections were registered through the WPB Aircraft Branch which echoed, in effect, the opposition of the AAF. W. J. Augustine of that branch opposed the move as (1) sheer duplication of the work of existing agencies, including Wright Field, the NACA, and the NDRC, and (2) "an interference rather than a help in speeding the use of new developments in the aircraft industry." At the same time a National Resources Planning Board witness (Dr. Robert Leigh) agreed that aeronautics needed no more "cooperation," since aeronautics was one of two or three fields of science "where cooperation and research between government and private industry is very well developed."[105] An expansion of this proposal came to the attention of Materiel Command

105. Transcript of WPB hearing, prepared "for record" by W. J. Augustine, 5 June 1942, and sent to Childlaw, 20 Oct. 1942; in Wright Development Engineering Branch file, 700.430 . . . Kilgore Committee.

[redacted]

Headquarters in September 1942, when a WPB employee--a

> Senior Program Procedure Analyst (whatever that is) came wandering into my [Col. B. M. 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 damned reluctant to put out too much, I started doing most of the question asking myself.

The WPB employee left a draft of the proposed directive with Colonel Chidlaw, 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 was already "too much coordination"; "the surest way to throttle [aeronautical development] was to set up another Bureau in Washington to smother it with committees, programs, meetings, priorities, and directives"; and the WPB's new prerogative would permit the WPB to "direct" research and development, to "control the time [the moment of standardization] when improvements in military equipment will be introduced into the production line," and to prevent the services from initiating any research project "without a certificate of necessity from the WPB."[106]

The War Production Board proposal, which was not widely publicized, was shortly withdrawn by Donald Nelson, WPB chairman, because of the intervention of the Under Secretary, but meanwhile a similar proposal was placed before the Senate by Senator Harley M. Kilgore. The directive

---

106. "Informal" memo by Chidlaw on "back history" of Senator Kilgore's proposal for an Office of Technological Mobilization, 10 Oct. 1942; and memo for USW by Echols, 26 Sep. 1942, both in AAF Development Engineering Branch file, 700.430 . . . Kilgore Committee.

[redacted]

of his proposed Office of Technological Mobilization (OTM), embodied in bill S. 702 in August 1942, was similar in language to the NRB proposal. The armed services, including the AAF, generally opposed it, on grounds such as those expressed by Colonel Chidlaw the month before. Likewise most of the spokesmen for industrial and university scientists opposed it, but with more emotional and less reasonable phraseology, including warnings of "regimentation," of the destruction of "freedom and the competitive spirit," and of "totalitarian powers that should be entrusted to no human beings."[107] In fact, some of their arguments, that the new OTM would impose centralized control over science, contradicted some of the Army arguments, that the OTM would result in divided and conflicting controls. On the other hand, a few advocates did support Senator Kilgore, including a union of scientific workers, Butler Brothers (jobbers who dealt largely with small firms), a minority of scientists, and Henry J. Kaiser and a few other industrial executives.[108] Dr. Vannevar Bush, the director of the Office of Scientific Research and Development (including the NDRC), whose position was of course threatened by the bill, agreed that wartime "centralized control" was necessary but argued that this was already being accomplished through the NDRC's "finely meshed machinery" of Army-Navy-civil scientific relations.[109]

---

107. Statements reprinted in Science, 7 May 1943, pp. 407-12, 436-37; 14 May 1943, pp. 438-39, 442-43, 510-11; and 4 June 1943, pp. 508-09; and Journal of Applied Physics, May 1943, p. 203 and July 1943, p. 311.
108. Hearings . . . S. 2721, Oct.-Dec. 1942, before the Kilgore Committee, especially pp. 215-22, 234, 509, 513; and New York Times editorial [about May 1943], reprinted in Science, 28 May 1943, p. 423.
109. Bush to Kilgore, various public letters, reprinted or summarized in Science, 31 Dec. 1943, pp. 572-77.

[redacted]

The AAF point of view toward such a scientific high command was expressed as follows, by Colonel Chidlaw, in October 1942:[110] "there is too much so-called 'cooperation'"; "we are about to be killed with kindness and cooperation--we are slowly being helped to death!" and

> 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 specialized personnel available in aeronautics to handle such work:

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

The Kilgore proposal eventually expired, after being revived in 1943 and 1944 in other forms. AAF control over its own development program was probably never seriously threatened; and aside from the burden on the AAF in marshaling data for the committee, an incidental

---

110. "Informal memo" for Brig. Gen. B. E. Meyers by Col. B. .. Chidlaw, 10 Oct. 1942, and "memo report for record" by Chidlaw, 12 Oct. 1942, both in Exp Development Engineering Branch file, 700.430 . . . Kilgore Committee.

[redacted]

benefit might have accrued to the AAF. The committee and its proposals and testimony probably did serve as a "gadfly" on the AAF and the other procurement services.

More important than a hierarchy of interagency 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 by the NACA, by educational institutions, and occasionally by other governmental laboratories; (2) experimental development, at Wright Field, by the Navy Bureau of Aeronautics and by 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 1939.

AAF Technical Collaboration with the Allies, 1939-1945

It was America's combined Army, NACA, industry, and university scientific establishments, described above, that developed virtually all the airplanes and air weapons used by the AAF combat forces during World War II. At the same time, the AAF research and development program both appreciably influenced and was influenced by similar or parallel scientific work on aeronautics going on concurrently in the several Allied nations during the war.

[redacted]

Scientists for generations if not for centuries had proclaimed that science and technology know no national frontiers. In actual practice, however, the international exchange of scientific ideas throughout history had been something less than complete because of barriers of language and distances, nationalistic sentiments and policies of particular scientists or scientific groups, national policies of particular governments in war and peace, national patent policies, and cartels and other commercial and industrial agreements which, while they may have been "international" in some aspects,[111] may actually have restricted applied science to particular groups or individuals. All these are factors to consider in portraying a more realistic pattern of international science, and in understanding and appraising the extent to which technical data were exchanged between the AAF and foreign air forces.

Collaboration between the Army Air Corps and friendly foreign governments in World War II followed such a pattern of international technological relations as suggested above. Historically these exchanges go back at least to World War I. In 1917 and 1918 the British and French supplied America with design data on its combat airplanes, a contribution which in the aggregate was doubtless greater than the aeronautical ideas supplied to them by the United States during those years.[112] After the

---

111. Cartels, it may be argued, are international agreements in the sense that particular firms in two or more countries have an agreement for the exchange of certain commodities or services; yet the exchange is actually restricted to those firms and may indeed be at cross purposes with policies of their respective nations.

112. See pp. 17-18, this study.

[redacted]

Armistice of 1918 the official exchange of technical information between the Army air arm and foreign air arms normally went through the system of American military attachés, who were duly accredited to foreign governments by the State Department. The technical reports on military aeronautics written by American military attachés, as well as by military air attachés and naval attachés, were voluminous;[113] but their quality and usefulness to the Air Corps varied according to the degree of entrée into foreign establishments,[114] the ability of the observers to perceive and understand the engineering problems involved, their awareness of the importance of scientific facts to the development of American air power, and the actual utilization of foreign technical data by Wright Field engineers and American industry.[115] The inexperience of junior officers or the indifference to aeronautical developments on

---

113. Most if not all military attaché reports for the period 1919-1939 received by the AirCorps from abroad through G-2 are in the files of the former OCAC Information Division, now in custody of AFSHO; copies of reports on airplanes and air equipment are in the Technical Data Library and in the central files of Headquarters ATC, Wright Field.

114. Thus, in 1924 a McCook Field official stated that both Great Britain and the United States had taken steps against "permitting members of each country to obtain any information [from the other] relative to aircraft development." (J. B. Johnson to Prof. Jasper, University of Illinois, 18 July 1924 [abstract], in ATC 360.02, Aeronautical Problems, 1928).

115. The Chief of the Experimental Engineering Section at Wright Field complained in 1939 that no one was specifically charged with obtaining and disseminating such information within the Materiel Division. While the Technical Data Library received all these documents and "filed" them, their dissemination and utilization was apparently inadequate. Examples of these problems in the field of bomber turrets are discussed in the draft ATC historical study, "Power Turrets."

[redacted]

the part of some of the military attachés were rectified in part by special Air Corps missions that occasionally were sent to Europe, including the trips by Brig. Gen. William E. Mitchell in 1922 and Maj. E. L. Powers in 1936.[116] In July 1938 the Air Corps, aware that special missions might be more successful than "routine" military attaché observations, sought to send such a mission, to be headed either by the Chief of the Air Corps or his ranking assistant, to visit the "principal aeronautical plane, engine, and equipment manufacturing establishments in England, France, Germany, and Italy"; but the plan was vetoed by higher authority.[117] Whether or not as a result of this restrictive policy, the state of Air Corps knowledge of foreign materiel was inadequate when the Milner Board early in 1939 was deliberating on a five-year research and development program for the Air Corps. Its recommendations, the Chief of the Air Corps later stated, could rely only on "theoretical conclusions" as to foreign aviation.[118]

---

116. See Maj. E. L. Powers, Visit of MD Representative to Europe, Nov. 1936, in AFHO 360.02, Research and Development.
F. F. Wright, while he went to Europe in 1937 as an executive of the Curtiss-Wright Corporation, nevertheless made his report available to the Air Corps. (See his report, Feb. 1937, in AFHO 360.02, Observation of Aircraft in Foreign Countries, 1937.)
There were probably other missions as well. The Engineering Division in 1925 (see its Annual Report, 1925, p. 35) urged the "utmost importance" of sending another mission like the Mitchell mission to Europe, to observe and study "the aeronautical industry, experimental and research laboratories, and the operation of the European air service[s]."

117. Retrospective comment, in memo for C/S by Maj. Gen. H. H. Arnold, 2 Jan. 1940, on "Urgent Necessity for Air Mission Abroad," in AAG 334.8, Missions.

118. Ibid. It is apparent that the weakest portion of the Milner Board report of May 1939 is in its characteristics charts for foreign airplanes. See pp. 28-29, this study.

[redacted]

At the same time (1939), the Air Corps was making available much advanced technical information to friendly foreign governments, especially to England and France. By an increasingly liberal foreign "release policy" from 1938 to 1940, some of the latest Army airplanes and equipment were being turned over for production by American industry and sale to foreign purchasing commissions.[119] This policy was consciously planned and executed less as a means to encourage the exchange of technical data with potential Allies than to stimulate the American aircraft industry and to help fortify the Allies.[120] Yet the Air Corps saw in the release policy an opportunity to profit by the experimental engineering of foreign governments and to use foreign battlefields as a "proving ground," in effect, for testing American-developed airplanes and air equipment.[121]

Within a matter of days after the outbreak of the European war in September 1939, the Air Corps again sought to send special observers

---

119. See Aeronautical Board, "Outline of Policy . . . for the Release of Aircraft . . . for Export and Domestic Sale . . .," 23 Aug. 1939, in A. J. Lyon project record book No. 15.

120. The various "foreign release" policy documents rarely mention reciprocal exchange of technical data. One Army-Navy Munitions Board Clearance Committee directive of 1 December 1939 does, however, acknowledge that aspect of foreign release. See AAG 334.7, Boards, Misc.

121. Lecture by Maj. Gen. H. H. Arnold before Army Industrial College, 23 Feb. 1940, copy in AIC Library.
Likewise, when the Lend-Lease bill was being considered in January 1941 to replace the foreign sales policy with a policy of outright transfers of Air Corps equipment to the Allies, the Secretary of War expressed the hope that "as a by-product" the United States and Allied nations would improve each others' airplanes and equipment and "combine the best results of the experience of both ourselves and the other nations." Quoted in JAC minutes, 2 May 1941, and in memo for Lt. Col. E. L. Powers by Col. A. J. Lyon, 29 March 1941, in AAG 032, Legislation.

[redacted]

abroad, this time to the same four countries as well as to Poland. Again the Air Corps was restrained, this time by the foreign governments themselves, which now refused permission.[122] Later, in January 1940, the Air Corps again sought to send missions abroad, one each to the United Kingdom and to Germany, each to be headed by an Air Corps general officer. The mission to Germany was obviously out of the question for political reasons, but the British from that moment did admit various Air Corps observers, who under various missions remained in England throughout the entire "defense period," as well as during the "war period" after Pearl Harbor.

Among all the Allies and potential Allies, the British were at once the strongest technologically and the most closely associated with the United States during the war on research and development matters.[123]

---

122. Memo for C/S by Gen. Arnold, 2 Jan. 1940, in AAG 334.8, Missions. The British Air Ministry about five weeks earlier (26 July 1939) had, however, invited the Chief of the Air Corps "or other senior officers representing him" to come to the United Kingdom to study its aircraft design, performance, armament, armor, tactics, and employment. (Ibid.) What action was taken by the Air Corps or the General Staff on this invitation is not known.

123. As to the other principal ally in Europe--the U.S.S.R.--there was very little exchange on experimental projects during the war. As of November 1944, for example, AC/AS, Intelligence stated that technical data in the AAF on Soviet aviation was "limited to those [aircraft] actually in operational use." (Memo for U.S. Military Mission, Moscow, 30 Nov. 1944, in AAG 360.2, Development and Research). There were several missions from both sides during the war, notably the U.S.S.R. technical mission in 1941, which inspected the B-17D and P-25A; the Soviet Government Purchasing Commission, which had access only to production models; Maj. Gen. Follett Bradley's trip to the U.S.S.R. in September 1942, when he saw production items only; and an AAF mission on aeromedical matters, about May 1944. Doubtless neither party revealed even all of its production models of airplanes and equipment. Thus the Sperry bomb sight, for example, was being withheld from the U.S.S.R. as late as November 1942; the reason given was that AAF production was not enough to supply even all of the AAF's bombers. (Memo for MAB by C/S, Materiel Command, 17 Nov. 1942, in AAG 350.05, Military Information.)

[redacted]

Behind the many technical delegations and missions that were exchanged with the AAF lay the influence and stimulation of the political and military consultations between President Roosevelt and Prime Minister Churchill, beginning perhaps as early as 1940 and continuing throughout the war, notably at the Atlantic Charter meeting in August 1941 and the successive conferences in Washington in 1941 and 1942, and at Quebec, Casablanca, Cairo, and Tehran in 1943 and 1944.

The earliest and most profitable Air Corps missions to England were those headed by Lt. Col. I. C. Eaker and Maj. Gen. Delos C. Emmons[124] in 1940, on aircraft and air materiel and tactics in general; Lt. Col. Grandison Gardner and Maj. F. O. Carroll in 1940, on armament;[125] Maj. A. W. Marriner in 1940, on radio and radar equipment; and Maj. Gen. H. H. Arnold in 1941,[126] on turrets, jet propulsion, and other aspects of air materiel and tactics. In July 1941 Air Corps technical interests in the United Kingdom were made permanent through the Air Officer of the Special Observer Group (SPOBS), the latter having been set up to plan for ultimate participation by the U. S. Army in the European War.[127] The Air Technical Section set up under ETOUSA in July1942, concerned with following

---

124. Brig. Gen. George V. Strong, WDGS, War Plans, and Maj. Gen. Delos C. Emmons, GHQAF, "Observations in England," 25 Sep. 1940, in Air Intelligence Library, England 9000.
125. Report by Gardner and Carroll, 1 July 1940, in ATSC Library, Doo/232; cited in ATSC historical study, "Development of Aircraft Gun Turrets," Chap. 5, n. 24.
126. Copies of General Arnold's cablegrams on his mission in April 1941 are conveniently filed together in AAG 311.22, Cablegrams.
127. C.S. (47) 13, 15 July 1941, prepared by British Joint Staff Mission; and cablegram, AG to London, 23 Oct. 1941, in AG 211.99, Liaison Officer (9-16-41).

[redacted]

the progress of the British research and development program rather than with war planning, was headed first by Brig. Gen. A. J. Lyon and, after Lyon's illness and subsequent death back in the United States in December 1942, by Col. H. G. Bunker who arrived in theETO in February 1943. Under various organizations in the European Theater of Operations,[128] the Air Technical Section functioned continuously from 1942 to 1945, and its key personnel included at one time or another some of Wright Field's best engineers, including (in addition to Lyon and Bunker) Cols. Benjamin S. Kelsey, Ralph P. Swofford, Howard M. McCoy, and Frederick R. Dent.[129]

While the Air Technical Section was the AAF's permanent liaison office in the United Kingdom on research and development matters, additional special delegations were from time to time sent from the United States. Notable among them were the missions of Col. D. G. Lingle in 1942; the mission of Brig. Gen. B. W. Chidlaw, Brig. Gen. Grandison Gardner, and T. P. Wright (of the Aeronautical Resources Control Office) in March 1944;[130] and the delegation of AAF and industry experts in September 1944.[131]

---

128. From 10 July 1942 (GO No. 13, Hq. ETOUSA) to 21 Feb. 1944 as part of ETOUSA; in 1944 and 1945 in USSTAF. The Air Technical Section was transferred to Air Service Command-USSTAF by GO No. 19, Hq. ETOUSA, 21 Feb. 44, and redesignated the Directorate of Technical Services by GO No. 10, Hq. ASC-USSTAF, 1 March 44. MM&D and Materiel Command vigorously opposed the step as a move that would deny the ATS the "greater freedom of action and freedom from interference" and subordinate this research and development function to the operational function of supply and maintenance in the European theater. Minutes of MM&D staff meeting, 14 Feb. 1944, in M&S files.
129. Gen. H. H. Arnold to Gen. Carl Spaatz, 3 July 1944, in M&S Materiel Div. file, 18.100 Misc.-Gen.
130. Chidlaw's "personal memo" to Maj. Gen. O. P. Echols on his visit to the United Kingdom, about April 1944, attached to memo for AAF Board by Col. R. H. Macklin, 17 April 1944, in AAG 333.1, Inspection. See also MM&D Materiel Div., Daily Diary, 9, 14, 22, 29 Feb., 9 March, 6 April 1944.
131. MM&D Materiel Div., Daily Diary, 4 Sep. 1944.

[redacted]

Supplementing AAF representation in the United Kingdom were other American missions, notably the London Office of the federal-wide Office of Scientific Research and Development, from 1941 on, which collected voluminous files of technical reports, broadly on all phases of research and development--air, ground, and naval;[132] and Edward Warner of the Civil Aeronautics Board, 1941 and 1942, who was concerned especially with cooperation on aerodynamics research between the NACA and the British equivalent organization.[133]

Meanwhile British air missions were being sent reciprocally to the United States, beginning before 1939 and continuing under various organizations to the end of the war in 1945. As already mentioned, there had been since before 1939 a British purchasing mission in the United States, negotiating with the aircraft industry and the Air Corps for the purchase of production models of Army airplanes. After 13 September 1940 this mission, renamed the British Purchasing Commission, was officially represented in the "Army-Navy-British Purchasing Commission Joint Aircraft Committee," which allocated production capacity among the three claimant air services (Army, Navy, and British) and reached agreements for standardizing production models of aircraft and equipment that might be of common operational use to all or some of them.[134]

---

132. Lists of most of these reports, and copies of many of them, are filed in Air Intelligence Library.

133. Warner to C. W. Lewis, NACA, 23 April 1941, in AAG 381.3, Lend-Lease Aid (filed under 12 June 1941); and Warner to D. M. Fye, Director of Scientific Research, British Ministry of Aircraft Production, 3 Feb. 1942, and reply by Fye, 13 Feb., in AAG 400.112, Test, Development Work. The NACA also attempted independently to "pick the brains" of the British through inquiries via the military attaché in London. See NACA, "List of questions submitted by NACA for Military Attaché, London," 7 Dec. 1940, in Air Intelligence Library, England 9000; and similar list dated 26 Nov. 1940, in ibid.

134. Draft AAF historical study, "Standardization of Air Materiel, 1939-44," Chap. III.

[redacted]

The standardization work of this committee, renamed the Joint Aircraft Committee (JAC) in March 1941, soon became concerned with experimental and service-test airplanes as well as with production models. As early as August 1940, at the Anglo-American conference at Wright Field at which the JAC was planned, all parties acknowledged the urgency of combining the lessons being learned from British combat experience with the technical advances being made by American experimental engineering, and of ironing out in advance any Anglo-American differences of opinion as to characteristics of new weapons, in order that "more mutually satisfactory airplanes[could be] made available to both countries in the future."[135] T. P. Wright, representing the recently established National Defense Advisory Commission at the conference, urged, in the interest of orderly production expansion, that the standardization of such future models be expedited by giving the British "blanket approval" to visit the experimental engineering departments in any American plants (except with respect to those planes or accessories that might be specifically exempted) and to fly or be flown in such service-developed aircraft for purposes of inspecting their characteristics.[136] The Chief of the Materiel Division promised, in connection with a proposed inspection trip by the British to various West Coast plants, to make technical data available at least on all production models, and offered to send along an Air Corps representative in order "to make certain that there was no reticence on the part of the

---

135. Minutes of Army-Navy-British-JAC conference, 27 Aug. 1940, in A. J. Lyon project record book No. 38.
136. Memo by T. P. Wright, 7 Aug. 1940, exhibit "F," in ibid.

[redacted]

manufacturers in discussing [standardization] issues."[137] The inspection trip was made and the British found it of "some value," especially in confirming among themselves the need for using American rather than British types; but they complained of the omission of experimental developments, "which are indispensable to deciding whether the improved model will be acceptable to [them]."[138] The Air Corps, on its side, was ready to give permission to the British to inspect planes, mock-ups, specifications, drawings, reports, and other information on such development projects as pressure cabins, self-sealing fuel tanks, turbo-superchargers, bomb-rack installations, and power turrets. But especially with respect to turrets, the Air Corps asked for the release by the British in turn of corresponding data on their own Frazier-Nash turrets;[139] and with respect to bombsights, the Navy, which controlled the procurement of the Norden model, was not ready to make the release. On 4 September 1940 a general information-release policy was transmitted to the British by the War Department, covering these exceptions but otherwise including "all data and access to all mock-ups and physical articles . . . required for the British-American mutual airplane production program."[140] Among the developmental projects soon to be inspected was the XB-29 long-range bomber, the mock-up of which the British were invited to inspect in November 1940.[141]

---

137. Report by T. P. Wright on conference of 13 Aug. 1940, in ibid.
138. Memo [for Materiel Div.?] by British Purchasing Commission [about 30 Aug. 1940], in ibid.
139. Ltr, Intelligence Div. to MD, 20 Aug. 1940, in ibid.
140. Memo for S/W by Chief, MD, 10 Sep. 1940, in ibid.
141. Minutes, Joint Aircraft Committee, 16 Nov. 1940. As of September 1940, however, no B-29's were allocated to the British by the Munitions Assignment Board of the CCS.

[redacted]

Eventually the process of mock-up inspection was the stage in the development of an article of equipment at which the British were generally called in for the purpose of "advance standardization." The decision in favor of this procedure was made early in 1941, after the Materiel Division heard a rumor that the British were planning to ask permission to participate in earlier pre-standardization phases of the research and development program.[142] The Materiel Division argued that the mock-up stage was the earliest moment at which the British ought to be admitted to a given right Field laboratory or industrial plant. Any earlier access, the Division stated, would endanger the American research and development program and prejudice it in favor of weapons "peculiar to . . . operations . . . in Western Europe, with a consequent decrease in developmental types suited to our own particular problems," presumably problems of future Pacific and western hemisphere operations.[143] This plea was upheld by General Arnold, then Deputy Chief of Staff for Air, who decided in March 1941 that Anglo-American "standardization as we now interpret it will start after mock-up."[144] British advice and recommendations, he stated further, should be obtained "as early" in the developmental stage "as this information can be obtained from them," and the "actual standardization" should occur "during the mock-up stage when

---

142. Memo for Brig. Gen. O. P. Echols by Maj. R. W. Chidlaw, 25 Feb. 1941, in AAG 400.112, Research and Development Program, F.Y.'s 1941-43.
143. Ibid.
144. Memo for Maj. Gen. G. H. Brett by Maj. Gen. H. H. Arnold, 11 March 1941, in AAG 400.112, Research and Development Program, F.Y.'s 1941-43.

[redacted]

the mock-up of a particular type is available."[145] In August 1942 this procedure was formalized by being added to the revised precept of the JAC Subcommittee on Standardization.[146]

The AAF remained constantly on the alert to insure that its research and development program would not be interruped by special British needs.[147] British attendance at mock-up inspections was again and again questioned by various staff sections of AAF Headquarters during the war. In June 1942, for example, the Directorate of Military Requirements sought to remove the British from this standardization process because the "British will, in the future, receive only a limited number of aircraft from this country."[148] This proposal, intended for the Joint Aircraft Committee, was withdrawn because of "repercussions" at higher echelons,[149] but it probably did influence the British to agree, in August, to give reciprocal privileges to AAF officers in the United Kingdom to participate in the "parallel" standardization of British-developed materiel.[150] In

---

145. Memo for Working Subcommittee on Standardization by Recorder, Army-Navy-British Purchasing Commission Joint Committee, 17 March 1941, in JAC file on Subcommittee on Standardization.
146. Revised "Precept of the Subcommittee on Standardization of the Joint Aircraft Committee" [about 20 Aug. 1942], in ibid.
147. For example, Lt. Col. E. M. Powers, AC, wrote from London about January 1942 in admiration of Britain's research and development program and added: "If we don't give our [experimental] projects high priority, they [British] will have designs developed and we may have to build them." MD Memo Report EXP-M-50-630, 12 Jan. 1942, "Research and Development," in ATSC 360.2, Research and Development.
148. Statement by Col. M. E. Gross, representing DMR, in SCS minutes, 23 June 1942, Item 17, in SCS minutes files, Vol. 8.
149. Minutes, SCS, 7 July 1942, in ibid.
150. Not until October 1942 was this reciprocal privilege established, however, presumably after the mission to the United Kingdom by Col. D. G. Lingle. See SCS minutes, 27 Oct. 1942, in SCS minutes files on case 3000.

[redacted]

August 1944 the AAF attempted to abandon mock-up inspection procedure,[151] an oblique move presumably to eliminate the British, if not the Navy as well, but apparently no action was taken. In November 1944 a decision by the Joint Chiefs of Staff permitted each service, such as the AAF, to disclose technical data to an Allied nation "only" when such information could be effectively utilized by that nation in prosecuting the current war.[152] This could have been used to exclude the British from inspecting virtually any project in an experimental stage, since it was doubtful whether any research and development projects still in the experimental stage in November 1944 would reach the combat stage in Europe in time for the end of the German war. Actually it was not until after V-J day that the Joint Aircraft Committee was abandoned and its standardization and mock-up inspection work was returned to its prewar status as a joint Army-Navy operation rather than as an Anglo-American problem.

In addition to British participation in the AAF's standardization and mock-up evaluation activities, various other British missions and delegations appeared from time to time in the United States to visit the experimental facilities of the AAF and industry and examine and gather technical data on experimental projects. Late in 1940, for

---

151. Memo for SCS by AC/AS, M&S, 29 Aug. 1944, in SCS file on case 3000.
152. Memo for Col. A. G. Bunker, ATS, by Col. J. F. Phillips, M&S Materiel Div., 6 Dec. 1944, discussing JCS Policy Memo No. 5, 28 Nov. 1944, released by TAG, 4 Dec. 1944; in AAG 350.05, Military Information.

[redacted]

example, a general scientific mission, originating in earlier negotiations between President Roosevelt and the British Ambassador in Washington, appeared from England under the leadership of Sir Henry Tizard.[153] The Tizard mission was introduced to a number of Air Corps scientific problems,[154] which apparently were taken back to the United Kingdom. Tizard's stay was only temporary; in part it duplicated the work of the British Air Commission.[155] After his return to England a British Central Scientific Office was set up in Washington to route American technical reports to England and to disseminate British technical reports to the services and scientific organizations in Washington.[156] There were still other British scientific delegations in the United States during the war.[157] Even "pretty women" were said to have been used on one occasion for furthering technological relations.[158]

---

153. Memo for C/AC by Lt. Col. Ira C. Eaker, Exec., OCAC, 28 Aug. 1940, in AAG 337, Conf. Misc. This memo lists the Air Corps representatives assigned to work with the Tizard mission.
154. Memo for Information Div. by MD, 9 Sep. 1940, in AAG 350.051, Dissemination of Information.
155. Maj. M. E. Gross wrote to Maj. A. J. Lyon, 10 September 1940, that the British Air Commission had "no love" for and "little cooperation" with the Tizard mission, and that both worked "at times" independently of the British Embassy in Washington. See A. J. Lyon project record book No. 38.
156. For example, see MD to British Central Scientific Office, 1 Aug. 1941, in AAG 400.112, Test, Development Work.
157. For example, see MD memo report, "Six RAF Pilots Visit Wright Field [30 Oct. to 3 Nov. 1941]," 10 Nov.1941, in Air Intelligence Library, "U.S. 9570 Airplanes"; and account of extensive visit by N. E. Rowe, British Ministry of Aircraft Production, to U.S. aircraft and engine plants, June 1944, mentioned in MM&D Materiel Division, Daily Diary, 19 June 1944.
158. With respect to the Norden bombsight, a Mr. Congrieve of the British Ministry of Aircraft Production stated (to the American military attaché in London in February 1940) that he had been instructed by a "high member" of the British air staff "that as he [Congrieve] has a most attractive American wife (she is), and as he himself has a pleasing personality, he should see what he could do where others had failed in getting the Norden Bomb Sight released to Great Britain." Report of Military Attaché, London, 12 Feb. 1940, in Air Intelligence Library, "England 9000."

[redacted]

In one sense there was much duplication between the British missions to the United States and the American missions to England, as well as duplications among the missions from one country. Yet independent appraisals and inspections of experimental projects by more than one party is a basic premise of all scientific inquiry, and scientific research on air weapons was no exception.

In any estimate of the extent to which experimental data were exchanged between the AAF and the RAF, it is apparent that the big decisions were made in 1940 and 1941. The British, on their side, made several notable transfers of data and equipment to the United States, especially the Rolls Royce engine in 1940,[159] radar for aircraft detection in 1940,[160] and the Whittle and Halford jet-propulsion power plants in 1941. These were the most widely publicized examples, but there were many other items on which American observers reported in voluminous reports from England to Wright Field and which they inspected in design, mock-up, or service-test stage.

On the American side, the Air Corps started out cautiously. In July 1940 many items were withheld from the British: all bombsights, the Norden models of which were controlled by the Navy; the D-type General Electric supercharger; the A-4 line of position computer; the A-5 Sperry automatic pilot; the latest type median sextant; microwave instrument landing equipment; the electric gyro-stabilized sextant; and "any" devices, instruments, or systems "under development which

---

159. See A. J. Lyon project record books Nos. 33, 33A.
160. See draft AAF historical study, "Radio and Radar Equipment for Air Operations, 1939-1944."

[redacted]

have not been manufactured for service test."[161] These restrictions, which (especially the last) would virtually have withheld data on the entire research and development program, were relaxed in August 1940, when the British were permitted to inspect the latest models of the B-28 (North American), B-25 (North American), A-20 and A-20A (Douglas), P-38 and P-49 (Lockheed), and B-17 (Boeing), and "to discuss with the manufacturers details of design and test and to [have] access to mockups and physical articles that are . . . essential to determine their suitability for standardized production."[162] On 4 September 1940 all these restrictions wer canceled,[163] except that bombsight data were still withheld and access to turret data was dependent on the "exchange for similar [data] on a British Frazier-Nash hydraulic turret."[164] By February 1941, the Air Corps was authorized to divulge data on any unclassified, restricted, or confidential research and development project without prior reference to the General Staff, but "secret" projects had to have prior clearance, and the Norden bombsight remained entirely closed[165] until after Pearl Harbor. From 1942 until the end of the war, British representatives inspected virtually every mock-up of a new airplane, and inspected many other experimental projects as

---

161. Memo for G-2 by OCAC, 25 July 1940 (extract), in AAG 350.051, Dissemination of Information, filed under 4 Sep. 1940.
162. Report on Army-Navy-British-NDAC conference at Wright Field, 27 Aug. 1940, in A. J. Lyon project record book No. 38.
163. Policy of 4 Sep. 1940, in AAG 350.051, Dissemination of Information. Whether the Tizard mission helped to liberalize this policy is not known. The mission did, however, appear in Washington shortly before that date.
164. Memo for Chief, MD, by Lt. Col. L. H. Smith, Western District Supervisor, 4 Sep. 1940, in A. J. Lyon project record book No.38.
165. MD O.M. 41-3, 10 Feb. 1941, in AAG 350.051, Dissemination of Information (filed under 6 Nov. 1941).

[redacted]

well, including (after about January 1943)[166] jet-propulsion projects and (after about December 1944)[167] guided missiles projects. Just which projects were consistently withheld from any British inspection cannot be said.[168] In general, however, it is probably true that the British at least knew of the existence, the general tactical objectives, and the characteristics of virtually every experimental project sponsored by Wright Field during the war.

The Frontiers of Research and Development, 1945

It might be argued that the air war was won by weapons developed between 1933 and 1941--by the B-17 and B-29, the designs of which were begun in 1933 and 1939, respectively; by the power plants for these bombers, developed between 1936 and 1941; and by bombsights and radar devices on which the basic work was done before 1941. All these and many other air weapons and supporting equipment were refined and improved in the course of the research and development programs between 1942 and 1945, but the chief emphasis of the later years, in terms of money spent and technical personnel employed in engineering projects, was on weapons that were not to become operationally available before the moment of the German and Japanese surrenders. Most of these projects

---

166. Jet-propulsion meetings in the AAF were still closed to the British as of November 1942. See Materiel Center Memo Report EXP-M-50-783, "Jet-Propulsion Meeting," 27 Nov. 1942, in ATSC 360.2, Assisted Take Off.
167. M&S Daily Activity Report, 4 Dec. 1944; OC&R Daily Activity Report, 16 Feb. 1945.
168. A list of experimental and production engineering projects "to be kept free from disturbance by British visitors" is mentioned in MM&D Materiel Division, Daily Diary, 23, 24 September 1943.

[redacted]

had high priorities for getting them into combat during the war, but the unexpectedly early end of the war in 1945 denied them the opportunity to test many of the weapons in combat. Jet propulsion, guided missiles, and the six-engine very heavy bomber were all designed for a longer war than was actually fought.

A rapid inventory of the status of AAF airplane models on V-J Day is pertinent at this point. The first-line combat airplanes in production or in tactical use as of 2 September 1945 included the following: the B-29 very heavy bomber; the B-17, B-24, and B-32 heavy bombers (the latter a wartime project already removed from the "very heavy" class and likely to be abandoned as a first-line tactical airplane); the B-25 and B-26 medium bombers; the A-20, A-26, and A-36 light bombers; the P-38, P-61, P-70 two-engine fighters; the P-40, P-47, P-51, P-63, and P-75 one-engine fighters; reconnaissance planes modified from the C-45, A-20, P-38, P-51, B-24, B-17, B-25, and B-29; the C-54, C-69, C-87, C-109 four-engine heavy transports; and the C-46 and C-47 two-engine transports.[169]

Still in the experimental or service-test stage at that time were the following airplanes: XB-39 and XB-44 (the B-29 with V-3420 engines and R-4360 engines, respectively); XB-42, the Douglas two-engine pusher; the P-59 and P-80 jet-propelled fighters of Bell and Lockheed, respectively; the XP-51D with additional rocket thrust; the XP-82 and XP-82A, double-fuselage fighter by North American; the XP-84

169. AAF Stat. Control Office, "Delivered Airplanes on Hand in the Army Air Forces . . .," 31 Aug. 1945 (SC-AI-26).

[redacted]

jet-propelled fighter by Republic; the XC-97 cargo airplane modified from the B-29; and the Fairchild XC-82 twin-boom "boxcar" cargo transport. Finally, still in the design and construction stage (as of 2 September 1945) were, among others, the following AAF airplanes: the Northrop YB-35 tailless flying wing, three flying mock-ups of which had been built between 1942 and 1945; the Consolidated-Vultee XB-36 high-wing, six-engine, 10,000-mile-range very heavy bomber; jet-propelled medium bombers by Douglas (XB-43), North American (XB-45), Consolidated-Vultee (XB-46), Boeing (XB-47), and Martin (XB-48); the Curtiss-Wright jet-propelled XA-43; the Northrop YB-49 flying wing, jet-propelled; the XP-86 jet-propelled fighter (North American); and the Consolidated-Vultee XC-99, a cargo version of the XB-36.[170]

In addition to these and some 25 other airplane models in various stages of design and experimental test, there were perhaps 1,000 or more supplementary engineering projects, also in various stages of experimentation at Wright Field when the war ended in 1945. Among the types of weapons and related projects represented were: pilotless aircraft, rotary-wing airplanes, and gliders; problems of aerodynamics, structures, armor, and landing gear; materials problems involving plastics, metals, textiles, and rubber; propulsion projects, including conventional engines, propellers, and ignition as well as the various types of jet and turbine units; fuels, propellants, and lubricants; bombsights, bomb racks, and fire control systems; navigation and flight

---

170. ATSC, "Research and Development Projects of the Engineering Division" (1 July 1945 ed.), in AFSHO.

[redacted]

instruments, including radar aids and "all-weather" equipment; aerial delivery equipment and cargo chutes; flying clothing, parachutes, and oxygen equipment; sea, land, and other emergency rescue equipment; and training aids.[171]

Behind these projects and supporting them there were at the end of the war also "on hand," so to speak, America's vast resources for scientific research and development that had been developed and subsidized, in effect, with funds provided by the AAF and the other services during the war. The expansion of these resources have already been described earlier in terms of laboratory facilities and trained personnel at Wright Field and Eglin Field, at the NACA, in the aircraft and related industries, and in the universities where aeronautical and other research was undertaken directly and indirectly for the AAF. Taken together these resources represented a scientific potential which, if not denied future projects and financial support, could become America's best insurance for aerial supremacy.

The future peacetime development of air weapons was of continuing interest in the AAF throughout the course of the war. Even before Pearl Harbor the Air Corps recognized that the fullest wartime expansion of laboratory facilities at Wright Field would be good postwar planning policy as well. In 1943 the Materiel Command began to plan its postwar program, and in August 1944 the first blueprint of the program—"Project B-7"— was available in AAF Headquarters.[172] The program covered the

---

171. Ibid.
172. "Scope and Procedure Plans, Project B-7, Post-War Research and Development Program, Five Year Period, F.Y. 1946 to F.Y. 1950 Inclusive," 28 Aug. 1944, in AAG 360.2, bulk files.

[redacted]

Engineering Division at Wright Field for the fiscal years 1946-1950, and proposed a technical personnel strength of about 750 officers and enlisted men and 6,500 civilians (annual average), annual expenditures ranging from 125 millions in 1946 to 80 millions in 1950, and a modest supplementary expansion of laboratory facilities at Wright Field. The report reiterated the traditional policies of the AAF as to cooperative research on air weapons: reliance on the NACA and its university contractors for exploring problems of fundamental research in aerodynamics, structures, propulsion, materials, and (since 1944) guided missiles; reliance on industry and universities, under contract with the AAF, for the application of fundamental research in the fabrication of airplanes and air equipment;[173] and the experimental and service testing of the materiel by the laboratories and installations of the ATSC and at other Army installations, chiefly at Eglin Field, Fla.; Great Falls, Mont.; Ladd Field, Alaska; and France Field, Canal Zone.

The postwar research and development program was amended in 1945 to include also the work of the proposed Research Board for National Security, set up with White House blessing to provide for postwar subsidy and support of fundamental research in nonmilitary institutions that might have military applications. This board, President Truman stated in June 1945, was to confine its activities to fundamental

---

173. The Engineering Division listed 14 key aircraft manufacturers, 33 manufacturers of related air weapons and equipment, and 7 universities where applied aeronautical and relating engineering and research could profitably be undertaken. Ibid., p. 96.

[redacted]

research and leave to the Army and Navy the prerogative to sponsor of undertake applied research based on the Board's work.[174]

A problem of more immediate urgency to the AAF was the maintenance and improvement of the high caliber of its key civilian engineers at Wright Field. In May 1945 the ATSC was directed by M&S to profit by the imminent demobilization of the scientific personnel of the wartime Office of Scientific Research and Development and to recruit them for duty at Wright Field "as the war effort diminishes." In order to offer greater inducements to such men, ATSC was further directed to utilize Civil Service pay scales to the maximum and to arrange that scientific personnel within the AAF "obtain recognition of their work through the media of signed and published reports" which they might write.[175]

What the future would hold for air weapons could only be foreseen as the war moved on to its conclusion. In May 1945 General Arnold outlined to General Marshall some of the potentialities of new developments in warfare that were likely to be realized in the foreseeable future. Jet propulsion, flying bombs, rockets, pilotless aircraft were all cited, including Germany's "amazing" V-2 and her "potentially more dangerous" devices, almost achieved, which could pour 600 rocket shells per hour into London. As to the atomic bomb as yet not tested, General Arnold reminded General Marshall of the "long range experiments in the field of advanced physics with elements capable of releasing unmeasured

---

174. President Harry S. Truman to S/W, 8 June 1945, copy in AFSHO.
175. Directive discussed in R&R, M&S to C/AS, 22 May 1945, in AAG 360.02, bulk files (filed under 18 June 1945).

[redacted]

forces . . . revolutionizing the field of explosives to the ultimate point of endangering human survival." Paralleling this potential weapon was biological and bacteriological warfare, which, General Arnold reported, the Japanese were "known" to be working on. All these weapons were "peculiarly adapted to air employment," he concluded.[176]

The combat tests of the atomic bomb over Japan in August 1945 electrified the world, including even the scientists who had been spending all their time during the war working on atomic fission. The AAF, as the tactical arm for the employment of the new weapon, was the arm that took the bomb over Japan. At the same time, the AAF as a procurement arm recognized the challenge to its existing research and development program being made by this new contender in the field of weapons of war. M&S, in sending out to ATSC Headquarters a copy of the Smyth report,[177] acknowledged that the releasing of atomic energy would probably make obsolete "to a considerable extent existing and presently envisioned military equipment," especially AAF materiel. The immediate official reaction in M&S and ATSC was not one of "military conservatism to new ideas," as the cliché has it. Instead, M&S saw in the control of atomic energy not only the achievement of a new explosive but also a means for propulsion of surface and subsurface vehicles, aircraft, and guided missiles and projectiles. The ATSC, meanwhile, had begun almost immediately to undertake "preliminary investigations and studies

---

176. Memo for C/S by General Arnold, 28 May 1945, in AAG 385, Warfare.
177. H. D. Smyth, consultant to Manhattan District, OCE, "A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government, 1940-1945."

[redacted]

of a general scope on the employment of atomic energy," and announced to AAF Headquarters that it was "prepared" to revise its research and development program as soon as the necessary channels were set up for getting access to the scientists and the data of the atomic energy project.[178] In this setting of a revolution in explosives and propulsion at the very end of the war, the AAF moved forward into the postwar era of its development.

---

178. Memo for ATSC by M&S, 18 Oct. 1945, "The Effect of Atomic Energy . . .," in AAG 360.2, Development and Research.

[redacted]

[redacted]

Chapter V

SUMMARY AND CONCLUSIONS[1]

The statement that "during the period 1918-1939 no new weapon was developed by or for the Armed Forces" is not borne out by the facts unless one insists upon the narrowest interpretation of the word "new."[2]

Virtually each of the 100 or more tactical airplane models developed by or for the Army's air arm between 1918 and 1939 might be regarded as new in the sense of having a new performance, a new range, a new speed, a new altitude, or a new fire power or striking power in comparison with its predecessors. The differences between the Martin bomber of 1918 and the Boeing XB-15 and YIB-17A of 1939 are too vast not to label the latter articles as new by contrast. Likewise the power plants, the armament, and the electronics equipment installed in the combat airplanes in 1939 bore little resemblance to those in use at the end of World War I. Also the standard engines, propellers, bombsights, turrets, and radio equipment of 1939 had little in common, in performance,

---

1. This chapter is both a summary of this study and a comparative analysis of AAF activities and those of selected foreign countries—England, France, Germany, Italy, the Soviet Union, and Japan. Data on these countries in this discussion are taken in large part from the AAF Historical Office study, "Comparative History of Research and Development Policies Affecting Air Materiel, 1915-1944" (June 1945), prepared for Scientific Advisory Group, Office of C/AS.
2. The hypothesis that "no" new weapons were developed between 1918 and 1939 is expressed in R&R, Scientific Advisory Group, Office of C/AS, to AAF Historical Division, about February 1945.

[redacted]

with their lineal ancestors of 1918. Some of them were gradual evolutions, while others were radical departures from 1918. Still other radical departures were the following projects which had been explored experimentally by 1939: an aircraft warning system, built in 1937 by the Signal Corps; radio-controlled missiles, tested at various times between 1919 and 1935; and jet and rocket propulsion, which had been studied under an Air Corps contract since December 1938.

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

The question arises as to how effective the AAF has been over the last 30 years in translating scientific ideas into better weapons, and whether other countries have excelled in solving any of the various phases of this problem. In some ways there are more similarities than differences. The research and development systems of the various military establishments throughout the world have had as many aspects in common as aspects that were dissimilar or unique. Thus, the whole body of procedures loosely called "the scientific method" is something that after all has no national boundaries. Next, the system of "military requirements" is an essential component of all air forces, whether

[redacted]

organized into a division by that name, an air staff office, or a committee system. Closely related to requirements is research planning: the Air Corps had its five-year program in 1939, and its five-year post-war program in 1945; so also with Germany and the Soviet Union inother years. Other problems are international or universal. Budgets, scientific personnel, the construction of laboratory facilities, and research contracts with industry and universities all represent problems that under different names have been common to autocratic and democratic nations alike, and common to World War I, World War II, and the years of peace in between--common in the sense that conflicting demands and priorities arose that reflected conflicts between development of the new and standardization of the old; between demands for quality and demands for quantity; between one field and another (for example, aerodynamics versus electronics, and internal-combustion power versus jet propulsion); and between military plans and civilian sources of scientific research.

National Attitudes

American appreciation for scientific research has probably been more vocal in the fields of the "practical" sciences than in "fundamental" or "pure science," difficult as it is to dissociate them. Edison, Ford, and Kettering are all well-known names in the last 30 years of American industrial history; scientific "symbolism" and laboratory stereotypes have been common advertising copy for a generation or more in the popular magazines; and the public has shown a normal interest in the Wright brothers, in the historical museum at Wright Field, and in the wind

[redacted]

tunnels at Langley Field. Much of this interest stems from a spontaneous curiosity of Americans toward new mechanical devices, but it has also been cultivated and inspired by planned programs of public relations--by commercial publicity for laboratory-developed consumer goods and by Army publicity in behalf of Army experimental activities. The generous release to the public of information on secret wartime aeronautical developments long before the German collapse in May 1945 is both a cause and an effect of this public interest in the gadgets of war. In other countries "popular science" has not been so vigorously cultivated except, perhaps, in the Soviet Union, where scientific accomplishments have been front-page news in the government-controlled press for a decade or more. The controlled press among the Axis powers, on the other hand, did not neglect scientific matters in its propaganda and information programs, especially where they were connected with problems of national self-sufficiency and military preparedness. Of these powers, Germany had inherited the most consistent scientific tradition, an inheritance which even the Nazi Government did not alter appreciably. But whether it was shared by the general public is debatable. Germany's historical attitude toward science, an interest in the theoretical foundations of applied science, was probably less a broad "popular" enthusiasm than an intellectual attitude shared by the small scientific elite of that country.

More important for aeronautical advancement than popular support of science has been popular support of military preparedness. In the United States, the prevalent indifference toward national preparedness before 1916 and from 1920 to 1939 is well known. This indifference,

[redacted]

variously explained in terms of pacifism, isolationism, and a preoccupation alternately with prosperity and depression, certainly had an adverse effect on scientific progress in military aeronautics, in spite of the fact that Army aviation after 1915 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 1923, in Japan in 1931 (or earlier), and in Hitler's Germany in 1933, and the popular consciousness and enthusiasm developed in those countries was usually carried over to military aeronautics as well. French and British sentiment for military aviation began to increase about 1936, but American opinion was not to become consistently favorable until 1939 and 1940.

National attitudes in the Axis countries were more consciously cultivated and planned by the controlled press, but even in democratic nations the articulate public opinion was hardly spontaneous. It would appear that in all countries--regardless of their political or economic structure--the governments have found it necessary to defend their programs for war research by means of propaganda, publicity, and public education: in Germany, Italy, and Japan, as a phase of national self-sufficiency and national superiority; in other European countries, as part 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 publicized not only as a tribute to America's

[redacted]

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, while American laboratories by the 1930's surpassed the rest of the world in their emphasis on "applied" science. Yet science in both countries, as indeed in all countries, was essentially utilitarian. Thus it is interesting that in 1910 Germany's scientific body for aeronautics, the Deutsche Versuchsanstalt für Luftfahrt (DVL), felt it necessary to defend itself against the charge of being "an unproductive scientific-theoretical organization." In later years German scientists and industrialists normally supported the DVL, although occasionally their interest did lag. On the other hand, American science, while "practical," did not wholly ignore "fundamental" or "basic" fields. Thus, it was America's Wright brothers who first studied fundamental aerodynamics with a wind tunnel (1903); it has been the superb and virtually unexcelled wind tunnels for fundamental research, built by the National Advisory Committee for Aeronautics, that have been praised almost unanimously by the aircraft and related industries; and it has been in some of America's larger corporate laboratories where basic theoretical aspects of electronics, metallurgy, and chemistry have been extensively studied.

[redacted]

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

As to the attitude of scientists to war research programs, their relationship to the military has varied. As with most countries, America has had many examples of the close inter-relationship between the development of peacetime products and the development of war weapons, a situation in which the impulse came as much from military requirements as from industry. For example, the steel industry was stimulated by the Navy's needs in the 1880's; the chemical industry was impelled forward by requirements of the Army in the 1890's; and the aircraft industry was essentially the result of military and other government subsidies in the 1920's. Scientists have usually supported war research programs, although in the 1930's some of the spokesmen of British and American

[redacted]

science castigated military projects as "the prostitution of science to war." 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.

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 these attitudes become 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. Whether in democratic or authoritarian countries, the political and military leadership has had to determine a policy for earmarking a portion of the national resources for military research, and these policies reflected such pressures as conflicts between tactical arms, between strategic policies, between various elements of the national economy, and between the demands for quantity as against the quality of the airplanes and weapons. Both in Italy and in America, for example, and probably in other countries as well, there were frequent pressures for standardization as against experimentation. Thus McCook Field in 1921 and 1922 was criticized by higher authority, even by high officers within the Air Service itself, because its experimental work was postponing quantity procurement. 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

[redacted]

development program was actually partially postponed for several months to permit the industry to concentrate on production. Another type of pressure was the resistance to the development of the heavy bomber in the 1920's and early 1930's, arising from conflicting strategic and tactical doctrines and viewpoints in the General Staff and the Navy. Yet during these two decades, 1920 to 1940, American military leadership ultimately supported, at least passively, the Air Corps experimental program. The Air Corps was able to embark on a substantial postwar program between 1919 and 1922; after a lapse of a decade, to initiate the heavy bomber program in 1933; and to undertake a five-year program in 1939. After 1940 there was no appreciable resistance from higher authority to the experimental program, and throughout World War II the AAF was able to pursue a highly accelerated experimental program, together with an unprecedented production program.

Measured by budgets and appropriations, the political support for aeronautical development in the United States was uneven during the period 1914-1945. Before 1915 Congress was apathetic to military aeronautics. Between 1908 and 1913 the United States was fourteenth among the nations in terms of government subsidies for aeronautics. Not until after war came in 1917 did Congress begin to support Army aviation in any substantial measure. As to the other nations: Germany, France, Russia, and Italy outranked the rest of the world up to 1914. 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

[redacted]

in substantial measure as late as 1922 in spite of the emerging period of peacetime "normalcy" and consequent hostility to military preparedness. The Soviet Union began to catch up after about 1927, with aeronautical research apparently a phase of its five-year programs. In republican Germany the Reichstag's "limited" interest after 1918 was reversed when Hitler came to power in 1933. British political support, which dropped in the later 1920's, began to be revived about 1936, after three years of watching the growth of Nazi Germany. American political support for aeronautical research dwindled badly between 1924 and 1934, and reached its lowest level in 1927, ironically near the moment of America's greatest financial "exhilaration." By 1930, however, the appropriations for the NACA fortunately rose steeply; after 1934 the Air Corps too was again being favored; and before war broke out in Europe in 1939 congressional support increased measurably and continued and expanded through the whole course of the "defense" period and the "war" period down to 1945. By 1942 appropriations were so adequate that some AAF officers could "complain" that they were finding it more and more difficult to utilize the budget efficiently.

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

[redacted]

By 1939 the estimated expenditures for scientific research (in all fields, aeronautical and otherwise, both for peacetime products and war goods) were about .6 of 1 per cent of the national income in the United States, .8 of 1 per cent in the Soviet Union, only .1 of 1 per cent in Great Britain, and perhaps .3 or .4 of 1 per cent in Germany. Since 1939 America probably has had no peer (except perhaps in the Soviet Union) in expenditures for war-related research. In 1944 about 600 millions were spent in the United States on scientific research, as against 250 millions in 1939. In 1944 almost all of this figure was involved in war research; in 1939, only a small fraction could be charged to military and naval projects. This "total" conversion of American science to war was comparable to the conversion of other elements of the national economy, and all of this expansion reflected a "bandwagon" policy of financial support for the military programs in wartime. Once aroused, the United States had no peer in lavishing financial support on its war machine.

Organization

Organized research has been necessary in all countries, especially in the fields of military aeronautics. Aircraft design and development is essentially a combined enterprise covering problems of military requirements, fundamental analysis, experimental design, prototype construction, service testing, and proof testing, all involving numerous agencies and institutions. Likewise the development of airborne accessories and ground equipment is a cooperative project, involving (in the case of the AAF in World War II) the Air Staff, the Air Technical Service Command, the Proving Ground Command, the National

[redacted]

Defense Research Committee, industrial laboratories, university scientists, and sometimes other supply services of the Army.

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

Between 1919 and 1939 the most notable organizational changes affecting aeronautical research were outside rather than within the Army. The NACA expanded out of its "advisory" status in World War I to become an actual research laboratory. Its first wind tunnel was completed in 1919, its laboratory construction program was accelerated in 1930, and by 1939 it probably had no peers throughout the world in terms of its equipment. Another notable nonmilitary organization in this period was the Daniel Guggenheim Fund for the Promotion of Aeronautics, established in 1926 as an endowed foundation and destined profoundly to affect aeronautical education throughout the United States.

[redacted]

Still another scientific group was the National Research Council and its "parent body," the National Academy of Sciences, concerned with fields other than aeronautics. Their war committees were demobilized after 1918, but the main organization survived as a "scientific adviser" to whatever federal agencies chose to use their services. Although they regarded their role as passive, the NRC and the NAS did sponsor a limited number of projects for the Air Corps before 1939.

The Army air arm's organization for research and development was relatively simple and consistent throughout the whole period 1917-1945. Thus, the ultimate control and supervision of the research and development program was in the procurement-tactical arm, with its authority stemming from the Constitution itself and with a framework that included a system of military requirements and staff supervision in Washington. Within this arm, the work was decentralized to McCook Field (after 1927 at Wright Field). These experimental activities, furthermore, came under the same jurisdiction as quantity production and procurement, both in the AAF's single materiel organization and in the corporate structure of each firm in the aircraft industry. Direct collaboration with the sources of research was relatively consistent, even when there existed intermediary agencies such as the National Research Council, the National Academy of Sciences, and the National Defense Research Committee. Occasionally there were reorganizations in the materiel agency of the AAF, but most of them were merely changes in name rather than changes in substance and policy. This organizational pattern was relatively simple, in contrast to the elaborate and sometimes overlapping organizations of scientific committees, councils, and

[redacted]

associations thriving among civilian scientists in the United States, and in contrast to the "over-organized" scientific structure in France and the "overlapping and duplication" of "coordinating" bodies in Germany.

At the same time there have been elements of organization that were rather uniform among all countries. Most of them had an NACA for both fundamental research and for coordinating fundamental research in aeronautics elsewhere. Frequently this was patterned after the American committee, although how far this similarity extended in actual practice cannot always be demonstrated. Most of them, too, had a National Research Council, such as those in Germany (1912), England (1915), the United States (1916), Italy (1921), and France (1922).

Scientific Personnel

The Army air arm's basic policy, consistent since 1917, has been to use scientific and industrial specialists in its technical projects. In World War I industrial managers from the aircraft, automotive, and other industries, together with scientists like Millikan and Mendenhall, were given military commissions or civilian jobs in the Air Service in connection with research and experimental projects. Both McCook Field and Wright Field technical personnel were preponderantly civilian from their origins. The engineers and scientists among them, both officers and civilians, frequently came from America's best technical schools and in some cases from industry, and their training was supplemented (for the officers) by the Engineering School at Wright Field and by civilian institutions like Massachusetts Institute of Technology,

[redacted]

California Institute of Technology, Michigan, and Stanford (most of them endowed by Guggenheim). Officer attendance at such schools was authorized by congressional legislation unsurpassed anywhere in the Army or in the rest of the federal government. Not an unmixed blessing was the fact that many of them in turn left the Air Corps to become prominent engineers in the aircraft and related industries. In World War II many Wright Field civilian experts were given military commissions, and were supplemented by aeronautical engineers commissioned from industry and by other scientists brought in both to Wright Field and Washington, including groups like those of Dr. Edward L. Bowles and Dr. Theodore von Karman, as civilian advisers to General Arnold and the Air Staff.

In both World War I and World War II the air arm probably suffered because America's scientific manpower, especially its younger engineers, were not entirely exempt from active military duty under the Selective Service System. This was not unlike the situation in England, which in 1914 permitted one of its most outstanding young physicists (Moseley) to become a casualty on the battlefield. In World War II both England and America remedied much of this waste of scientific manpower by means of national registrations of scientists and better policies for occupational deferments, but not all problems were solved. The practices in other countries varied: France apparently was permitting no draft deferments in 1940, while Germany was the most consistent in mobilizing its scientists for specialized war work. German policy was partly negated, however, by its radical 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.

[redacted]

Another practice for improving materiel development has been to import scientists and other specialists from abroad. The Soviet Union and Japan in earlier years were the outstanding examples of such a conscious policy. After 1933, England and America, without a particularly definite national policy or a conscious scientific objective in view, did nevertheless profit by giving haven to refugee scientists.

Production of New Weapons

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

There has never been any basic, irreconcilable conflict between the needs for "quality" weapons and "quantity" production, perhaps because those who developed new materiel also ultimately were expected to produce it. Thus in the aircraft industry, for example, the experimental design staffs and the assembly lines are normally parts of the same firm, under the same management. Likewise in fields outside of aeronautics most of America's scientific research is done in

[redacted]

industrial rather than in nonindustrial laboratories, and the firm that manages the research also normally manages production. This is as true in the peacetime economy as in wartime. If American scientists have been "accused" of being preoccupied with the "practical" side of research, the reason for it is a blessing in disguise: most of America's scientists are either hired directly by industry or their university projects are subsidized by industry--by the same firm that is most likely to produce the end product, whether a bathtub or a guided missile. This civilian 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 materiel center at Wright Field. This materiel center is primarily a monitor of industrial research rather than an independent laboratory; and the continuous problem both at Wright Field and in the air staff in Washington is to effect the best compromise between experimentation and production, between quality and quantity, between striving for perfection and falling in obsolescence. In addition, one specific AAF device for rationalizing these pressures should be mentioned--the system of modification centers established after 1941. By this means, newly developed equipment is installed on standard airplane models as a separate process after the plane leaves the assembly line; and ultimately at the proper, predetermined moment, the special installation is incorporated in the assembly line with the minimum of interruption to the production process.

[redacted]

Strategic Planning of New Weapons

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

On the eve of World War I the small nucleus of airmen in the Army were aware of the tactical and strategic functions of air power, but no combat plane had ever been designed or built in the United States up to that time. World War I itself was for the American Air Service an operational problem on the European Continent only; America's war planes were largely those developed in Allied countries for 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. The Martin bomber designed and built experimentally in 1918 symbolized the rise of independent strategic thinking in the Army Air Service, and the doctrines of strategic bombardment expounded by Mitchell and others became the foundation for the Air Corps research and development program in the 1920's and 1930's. In 1933 the Drum Board approved the air war plan for operations to be based on the

[redacted]

American Continent, to be directed first toward European targets and ultimately toward the Far East. The Board, furthermore, accepted the defensively self-sufficient heavy bomber as the primary weapon for the air war. In the same year the designs of the XB-15 and XB-17 were begun, and the Air Corps research and development program began in earnest, centered around this fundamental bombardment mission. The development and testing of these two models between 1933 and 1939 led directly to the heavy bombers that were used in the European theater after 1941 and the long-range very heavy bombers used in the Far East after 1943. The wartime improvements of these experimental bombers after 1939 were, of course, substantial and vital, but they were not based on any fundamental change of strategic doctrine. Instead, they represented solutions to tactical difficulties and problems encountered by the RAF and the AAF in 1940 and thereafter. The bombers planned and designed in the early 1930's were essentially those that won the air war in the German and Japanese theaters in World War II. America's fighter-bomber was acknowledged by the head of the defeated Luftwaffe as the one new weapon that helped to win the air war in Europe.

Aside from our own offensive, strategic weapons--illustrated in the strategic bomber--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

[redacted]

use at that stage of the war was unexpected, and the Allies did not achieve any basically effective countermeasures against them except to strike directly at the enemy's installations where those weapons were being produced and launched, and to push forward relentlessly with the ground-and-air cooperation operations across the Continent after June 1944. Had the enemy's new missiles appeared in greater strength and with greater precision a few months earlier, the Allied landings on D-day might conceivably have been prevented. Obviously the development of countermeasures is as vital as the development of our own strategic weapons.

Whether America's present air weapons are adequate for coping with future strategic objectives is another problem. The remainder of the Japanese war was fought with weapons long under experimental development. As to the immediate postwar years, with the fallen enemies remaining in a state of military collapse, it seems obvious that the best weapons now under development—the new very long range bombers, the most advanced radio and radar aids, the newer air-launched controlled missiles, and the atomic bomb 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

[redacted]

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 30 years. These problems, factors, and issues are those that have been discussed and explored in this study: 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, the White House, and the War Department; proper utilization of the nation's scientific talent in the laboratories of industry, universities, the AAF, and 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 arises.

[redacted]

[redacted]

G L O S S A R Y

AC	Air Corps
AC/AS	Assistant Chief of Air Staff
ACO	Air Communications Office
ACTC	Air Corps Technical Committee
AFSHO	AAF Historical Office
AIC	Army Industrial College
AS	Air Service
ASF	Army Service Forces
ATS	Air Technical Section
ATSC	Air Technical Service Command
AS/W	Assistant Secretary of War
BAP	Bureau of Aircraft Production
BTO	Bombing Through Overcast
Bu. Aer.	Bureau of Aeronautics
C/AAF	Chief of Army Air Forces
C/AC	Chief of Air Corps
CCS	Combined Chiefs of Staff
C.I.T.	California Institute of Technology
C/S-E	Chief of Staff—Experimental
D.C/AS	Deputy Assistant Chief, Air Staff
DC/S	Deputy Chief of Staff
DMR	Directorate of Military Requirements
dsgd	designated
EES	Experimental Engineering Section
Eng	Engineering
ESMR	Engineering Section Memorandum Report
estbd	established
ETO	European Theater of Operations
ETOUSA	European Theater of Operations, U. S. Army
GAX	Ground Attack Experimental Airplane [in 1920's]
GHQAF	General Headquarters Air Force
JAC	Joint Aircraft Committee
JCS	Joint Chiefs of Staff
L.I.	Letter of Instruction

[redacted]

MAB	Munitions Assignments Board
MC	Materiel Command
MD	Materiel Division
MIT	Massachusetts Institute of Technology
M&D	AC/AS Materiel, Maintenance, and Distribution
M&S	AC/AS Materiel and Services
NACA	National Advisory Committee for Aeronautics
NAS	National Academy of Sciences
NBS	National Bureau of Standards
NDAC	National Defense Advisory Commission
NDD	New Developments Division, AD General Staff
NDRC	National Defense Research Committee
NRC	National Research Council
NRPB	National Resources Planning Board
OASW	Office of Assistant Secretary of War
OCAC	Office of Chief of Air Corps
OCE	Office of the Chief of Engineers
OC&R	AC/AS Operations, Commitments, and Requirements
O.M.	Office Memorandum
OSRD	Office of Scientific Research and Development
OTM	Office of Technological Mobilization [proposed]
PGC	Proving Ground Command
R&D	Research and Development
SCS	Subcommittee on Standardization, JAC
SPOBS	Special Observer Group
S/W	Secretary of War
TAG	The Adjutant General
USSAFE) USSTAF)	United States Strategic Air Forces in Europe
WDGS	War Department General Staff
WF	Wright Field
WPB	War Production Board

[redacted]

[redacted]

BIBLIOGRAPHY

Historical Studies

Historical Section, Air Service, Historical Studies of the Bureau of Aircraft Production and of the Directorate of Military Aeronautics in World War, prepared about 1918-1919 and now filed in the AGO War Department Records Branch. This file of historical studies, together with working papers, consists of about 40 linear feet of material. Among the most useful works for this study were those on Aircraft Production . . . Advisory and Co-operative Agencies, by Lt. R. C. Hilldale; Langley Field, by Capt. H. H. Blee; the Factory Department at McCook Field, author unknown; the Bolling Aeronautical Mission, by R. M. McFarland; Science and Research Division, author unknown; and Airplane and Engineering Division, by Capt. H. H. Blee. The following files of working papers were also useful: 334.8 Bolling Mission; 360.05 McCook Field; and 452.1 Airplanes, General. Some of these historical studies were integrated into a 2,500-page "History of the Bureau of Aircraft Production," copy of which is missing from the above files but is available in the ATSC Historical Office (with a microfilm of the same in the AAF Historical Office). Portions of these historical files were used by Arthur Sweetser, in The American Air Service; A Record of Its Problems, Its Difficulties, Its Failures, and Its Final Achievements (New York, 1919, 384 pp.).

Historical Office, AAF Headquarters, AAF Historical Studies:

Communications Techniques in the AAF, 1939-1945 (draft, 1945)
Development of Tactics in the AAF (draft, 1944)
Legislation Relating to the AAF Materiel Program, 1939-1944 (1944)
Radio and Radar Equipment for Air Operations, 1939-1944 (draft, 1944)
Standardization of Air Materiel, 1939-1944 (draft, 1944)

Other studies by AAF Historical Office

A Brief History of the Army Air Forces (1943)
Review of Aerial Warfare for the Scientific Advisory Board [Group] (1945)
Comparative History of Research and Development Policies Affecting Air Materiel, 1915-1944 (1945)

[redacted]

Studies by the Historical Office, ATSC Headquarters and its predecessors:

"Case Histories" of selected development and procurement projects (1944--)
Development of Aircraft Gun Turrets (1945)
Development of Bombing Equipment (1945)
History of the Materiel Command, 1926-1941 (1944)

Studies by the Historical Branch, Proving Ground Command

Historical Outline of the Proving Ground Command
Index and List of Service Tests Activated at Eglin Field [1939-28 Feb. 1945], 2 vols., 142 and 100 pp.

Classified Central Files of AAF Headquarters (cited as "AAG . . .")

000.71	Interviews (Sep. 1944)
311.22	Cablegrams (April-May 1941)
333.1	Inspection (April 1944)
334	Boards, Misc. (Dec. 1944)
334.7	Boards, Misc. (Oct. 1933-Dec. 1944). Includes reports of Kilner Board, 1939, and Emmons Board, 1940.
337	Special Directors Conferences (April-Sep. 1942)
350.05	Military Information--Collection and Dissemination (Nov. 1942-Jan. 1943). Includes some data on exchange of technical data with Allies.
350-051	Dissemination of Information (March 1937-Oct. 1942). Same comment as on 350.05.
360.01	Programs (Jan. 1942)
360.2	Development and Research (Nov. 1942-Oct. 1945). Of primary importance.
380	Programs and Projects (March 1943)
381	War Plans (May-Dec. 1944)
381.3	Lend-Lease Aid (June 1941)
385	Warfare (May 1945)
400.112	National Advisory Committee for Aeronautics (Jan. 1938-Oct. 1942). Includes some minutes of executive committee of NACA.
400.112	National Defense Research Committee (Nov. 1940-Oct. 1942). Fragmentary data on NDRC policy; some NDRC reports included.
400.112	Test, Development, Research (1935-July 1942). Of primary importance. For later period, see 360.2.
452.1	Airplanes, General (Sep. 1940)
452.1	Production of Aircraft (Feb. 1942)
676.3	Wireless--Radio System (Dec. 1940)

[redacted]

Equally if not more important than the above correspondence files are the "bulk" files of oversize reports and other documents that are filed separately from the above. The best key to the use of this material is not the cross-references from the correspondence files but the detailed inventory-check list of bulk items, prepared by the AGO War Department Records Branch, 1945. Among the most useful bulk items are: List of Army aircraft, 1917-1922 (452.1); Drum Board Report, Oct. 1933 (334.7); Capt. C. S. Irvine's report on civilian personnel at Wright Field, 1939 (321.1); Kilner Board report, 1939 (334.7); Air Corps Technical Committee minutes, 1939 (334.8); Emmons Board report, 1940 (334.7); Col. Carl Spaatz' notebook, Nov. 1939-March 1940, on meetings attended by him (no file number); transcripts of telephone conversations by Col. Carl Spaatz, Maj. Gen. D. C. Emmons, and others, Sep. 1941-Jan. 1942 (311.3); War Department Council minutes, 1943-1945 (337); historical report by Dr. Edward L. Bowles, 1943 (334.7); and the B-7 program, Aug. 1944 (360.02).

Unclassified Central Files of AAF Headquarters (cited as "AAG . . .")

210.66	Detail to Civilian Educational Institutions (1938-1942). Occasional references to training of aeronautical engineers assigned to Wright Field.
300.6	Office Memos, Numbered (Feb. 1930-Oct. 1942). Includes some unnumbered memos (e.g., of the Directorate of Military Requirements), some AAF Regulations in 1942, as well as correspondence relating to them.
300.7	AAF Regulations (March-Oct. 1942)
321.9	Materiel Division (1927-Oct. 1942)
334.7	Aeronautical Board (Sep. 1939). Includes report of Air Board, 15 Sep. 1939, as well.
381.4	War Plans, National Defense (May 1940)
400.112	Fairfield Service Tests (March 1921-Sep. 1942)
400.112	Tests and Experiments (1920-Oct. 1942). Of primary importance.
452.1-17	Aircraft, Manufacture of (June-Sep. 1940)
475.73	Aeronautical Equipment (Feb. 1923-Oct. 1942)

Files of Development Engineering Branch, Materiel Division, M&S

(Since Dec. 1944, when these files were used for this study, they and the organization have been transferred to the Production Division, AC/AS-4; cited as "M&S . . .")

1.102	Military Characteristics
18.100	Misc.-Gen. (Dec. 1942-Oct. 1944)
18.400	Visits to Manufacturing Plants

[redacted]

30.105 New Developments Division [WDGS] (Nov. 1943-Sep. 1944)
30.109 Committee on Air Force Developments
30.1001 Joint Aircraft Committee
40.007 Daily Staff Meetings (Oct. 1943-Nov. 1944). Minutes.
50.121 Research and Development, F.Y. 1944 (Nov. 1942-Nov. 1943)
50.122 Research and Development, F.Y. 1943 (May 1941-April 1943)
50.123 Research and Development, F.Y. 1942 (Nov. 1939-Oct. 1942)
50.124 Research and Development, F.Y. 1941 (May 1939-Aug. 1941)
50.125 Research and Development, F.Y. 1940 (Dec. 1937-March 1940)
700.280 National Advisory Committee for Aeronautics (Aug. 1940-Nov. 1944)
700.430 Kilgore Committee--Office of Technological Mobilization (Oct. 1942-July 1944). Includes M&S study on research and development, 1939-1944; copies of bills, hearings, and reports of Senate Subcommittee on Technological Mobilization; and memoranda and statements on views of AAF and War Department on Senator Kilgore's proposals.

Classified Central Files of ATSC Headquarters, Wright Field, Area B (cited as "ATSC . . .")

230 Personnel (Sep. 1941-Nov. 1944), 1 vol. Includes some statistics on civilian technical personnel at Wright Field.
334.8 National Defense Research Committee (Aug. 1940-Dec. 1944), 1 vol. Includes descriptions and progress reports on many NDRC projects.
334.8 National Defense Research Committee, General and Policy (Aug. 1940-Oct. 1943), 1 vol. Contents indicated by title.
334.8 National Defense Research Committee, General (Jan.-June 1945), 1 vol. Chiefly descriptions and progress reports on specific NDRC projects.
337 Conferences, General, 1941 (June 1941-June 1945), 1 vol. Includes some minutes of staff meetings in MM&D.
360.2 NACA Policy (July 1941-June 1942), 1 vol.
360.2 National Advisory Committee for Aeronautics (Jan. 1939-Dec. 1944), 1 vol.
360.02 Navy Experimental Projects (Jan.-July 1945), 1 vol. AAF progress reports on Navy projects at Patuxent, C.I.T., Aberdeen Proving Ground, and elsewhere.
360.2 Take-off of Large Airplanes, Assisted Jet Program, NACA, 1940 (May 1940-June 1941), 1 vol. Chiefly NACA letters of transmittal.
360.2--452.83 Exhaust-Gas Jet-Propulsion, NACA, 1942 (Oct. 1939-July 1944), 1 vol.

[redacted]

362 Tests, Eglin Field (Feb. 1943-March 1945), 1 vol. Chiefly weekly reports of tests.

371.1 Theaters of Information, Information (Oct. 1943-June 1945), 1 vol. Correspondence with Air Technical Section in the United Kingdom, and many comments and suggestions from all theaters, chiefly "informal reports" sent to Wright Field for the attention of specific laboratories.

Unclassified Central Files of ATSC Headquarters, Wright Field, Area B (cited as "ATSC . . .")

045.2 Navy (Aug. 1944). Navy representation at Wright Field.

121.4 Funds, 1929

210.3 Assignment and Transfer of Officers, 1928 (Feb. 1927-July 1928). Civilian and military personnel for experimental work.

248.1 Estimates, Civilian Employees, Pay Roll Study, 1936 (July 1934-April 1935)

319.1 Annual Reports [Data], F.Y. 1936, 1937, 1938 (June-Dec. 1936, June-Aug. 1937, Sep. 1937-Aug. 1938), 3 vols. Portions of published annual reports of Chief of Air Corps based on these data. See also AAG 319.1 for these years.

321.91 Organization, 1929 (March-Nov. 1929)

333 Survey Military Establishment, 1929 (April 1926-Nov. 1929). Statement of "accomplishments" at Wright Field, 1928-29; Army's "economy survey," Aug. 1929; and memos on proposed consolidation of Army and Navy air materiel organizations and on proposed move of Technical School at Chanute Field to Wright Field, Feb. 1928.

334.8 Air Corps Technical Committee, 1928 (Dec. 1926-Aug. 1928); 1929 (Jan.-March 1929). Chiefly proceedings of ACTC. See similar files in AAG.

337 Engineering and Supply Conferences, 1928, 1930, and 1937. Agenda and minutes of annual conferences for years indicated.

360.01 Policy--Procurement, 1929. Includes chronology of materiel development, 1920-1929.

360.02 Aeronautical Problems, 1928 (March 1919-July 1928). Includes data on Air Service-sponsored university research, 1921, 1924.

400.112 Development Program, 1933 (Nov. 1930-Oct. 1933)

400.112 Government Aid to Educational Institutions . . . Engaged in Aeronautical Research, 1935 (Dec. 1934-Feb. 1935). Includes Guggenheim proposal of Dec. 1934.

[redacted]

Diaries and Daily Activity Reports

Filed in Historical Office, AAF Headquarters. Duplicates of some diaries are filed in AAG "bulk" files, as well as in AAG 319.1.

AC/AS Materiel and Services (July 1944-Aug. 1945)
AC/AS Materiel, Maintenance, and Distribution (April 1943-July 1944)
AC/AS Operations, Commitments, and Requirements, April 1943-Aug. 1945
AC/AS Plans, March-Dec. 1943
Director of Military Requirements, March 1942-March 1943
Materiel Division of MM&D and M&S, March 1943-Aug. 1945
Operational Plans Division, Aug. 1942-March 1943

Miscellaneous Files and Unpublished Documents

Col. A. J. Lyon's project record books, 1939-1941, pertaining to materiel and other projects monitored by the Office of the Chief of the Materiel Division; filed in Office of AC/AS-4. See "inventory" of Lyon books, in AFSHO. Volumes most useful for this study were Vols. 8 (military characteristics), 9 (research and development), 13 (Kilner Board), 15 (AC Technical Committee), and 38 (standardization).

Intelligence files, 1939-1945, in Air Intelligence Library, AC/AS-2. Includes reports of air observers abroad, 1939-1941, and reports from overseas air forces on materiel. Filed by country or area, numerically thereunder according to the "Index Guide" system for numbering military attaché reports. For files prior to 1939, see files of OCAC Information Division, now filed in AFSHO.

Joint Aircraft Committee:
Recorder's Office, file on "Subcommittee on Standardization" (1942).
Subcommittee on Standardization, Recorder's Office, minutes and case files, especially file on case 3000.

Materiel Command:
Office for Organizational Planning, "Evaluation of the Utilization of Airplanes Assigned or on Loan to Materiel Command (Final Report)", 11 Jan. 1944, in ATSC Organizational Planning Office. Includes some statistical data on airplanes used in experimental and service tests.
"Research and Development Projects of the Engineering Division," editions for Jan. 1944, July 1944, Jan. 1945, and July 1945 (the latter two issued by ATSC), all in AFSHO. Comprehensive handbook of selected experimental projects at Wright Field.

Statistical Control Division, AAF Hqs., "Delivered Airplanes on Hand in the Army Air Forces . . .," 31 Aug. 1945, in AFSHO. Includes listing of AAF airplanes according to developmental status.

[redacted]

Annual Reports

Air Corps, Materiel Division, "Annual Reports," 1927 to 1940. Not published. Blueprint copies, 1927-34, in War Department Library; typewritten copies, 1935-37, in ATSC 319.1 Annual Reports; and typewritten copies, 1939 and 1940, in ATSC Historical Office. Scattered copies also in AAG 319.1.

Air Service, Engineering Division, "Annual Reports," 1919 to 1926. Not published; reproduced by blueprints; filed in War Department Library.

Air Technical Service Command, Engineering Division, "1944 Annual Report . . ."; in ATSC Historical Office.

Army Air Forces:
Historical Division, "Biennial Report of the AAF," 1941-1943. Typescript in AFSHO.
Report of the Commanding General of the Army Air Forces to the Secretary of War, Jan. 1944
Second Report of the Commanding General of the Army Air Forces to the Secretary of War, 27 Feb. 1945

National Advisory Committee for Aeronautics, Annual Reports, 1919 to 1943. Normally divided into administrative and technical sections for each year.

National Academy of Sciences, Report, 1916; and Annual Reports, 1917 and 1918

National Research Council, Annual Reports, 1916 to 1919

Other Government Publications
(Arranged chronologically)

U. S. Statutes at Large.
Various statutes for years 1915-1942 cited in this study.

United States Code, 1940 Edition. Sections 10 and 50 used in this study.

Baker Board, Report, 1934.

Federal Aviation Commission (Howell Commission), Report, 1935.

National Resources Committee:
Technological Trends and National Policy, Including the Social Implications of New Inventions, 1937. Report of the Subcommittee on Technology.
Relation of the Federal Government to Research, 1939

[redacted]

Work Projects Administration, Industrial Research and Changing Technology. Report by George Perazich and Philip M. Field, published as WPA National Research Project Report No. M-4, Jan. 1940.

National Resources Planning Board, Industrial Research, 1941.

Hearings . . . Senate . . . Subcommittee on Technological Mobilization . . . S. 2721 [Oct.-Dec. 1942]. 3 vols.

Senate Committee on Military Affairs, Subcommittee on War Mobilization, Government's Wartime Research and Development, 1940-44. Part I.--Survey of Government Agencies, 1945. Part II.--Findings and Recommendations, 1945.

H. D. Smyth, A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government, 1940-1945 (1945). Published for the Manhattan District of the Office of the Chief of Engineers.

Directories of Scientific Agencies and Scientists

Aircraft Year Book, 1920-1943

National Bureau of Standards, Directory of Commercial Testing and College Research Laboratories in Universities and Industrial Concerns, 1927 (NBS publication M.90, April and Dec. 1927), 1929 (M.90 supplement), 1936 (M.125), and 1942 (M.171)

National Research Council, Directory of Industrial Research Laboratories in the United States, 1920 (NRC Bulletin No. 2), 1921 (Bull. No. 16), 1927 (Bull. No. 60), 1931 (Bull. No. 81), 1933 (Bull. No. 91), and 1938 (Bull. No. 102)

Treasury Department and National Bureau of Standards, Directory of Inspection Services and Testing Laboratories of the Federal Government, 1935 and 1944

Work Projects Administration, Writers' Program, Who's Who in Aviation . . ., 1942-1943 (1942)

Other Publications
(Arranged by date of publication)

Arthur Sweetser, The American Air Service . . . (1919)

Grosvenor B. Clarkson, Industrial America in the World War . . ., 1917-1918 (1923)

Ernest V. Hollis, Philanthropic Foundations and Higher Education (1938)

[redacted]

New York Times, 1939. Scattered references to state of scientific work on military aeronautics at the time of the outbreak of the European war.

J. D. Bernal, The Social Function of Science (1939). Includes discussions of the use of science in the development of weapons, and comments on the administration of science in universities, industry, foundations, and government agencies.

Science News Letter, 1939. Scattered references on the status of military research and development at the time of the outbreak of the European war.

Air Corps News Letter, 1 Aug. 1939. Anniversary edition devoted to the history of the Air Corps.

Edgar S. Gorrell, The Measure of America's World War Aeronautical Effort (1940)

Lt. Col. Frank O. Carroll, "Experimental Engineering [in the Air Corps]," in Flying and Popular Aviation, Sep. 1941, pp. 84-86, 208. Official statement by the Chief of the Experimental Engineering Section at Wright Field.

Reginald M. Cleveland, America Fledges Wings; the History of the Daniel Guggenheim Fund for the Promotion of Aeronautics, 1942. Discusses the importance of the Guggenheim Fund in the training of aeronautical engineers.

Tom Wintringham, The Story of Weapons and Tactics from Troy to Stalingrad (1943). General survey.

George W. Gray, Science at War (1943). General Survey.

"[Historical sketch of] National Advisory Committee for Aeronautics," in Journal of Applied Physics, Aug. 1943, pp. 399-405.

George W. Gray, "Trial by Wind Tunnel," in Harpers, April 1945, pp. 446-55. Sketch of NACA activities in wartime.

Interviews and Conversations
(Conducted by Dr. Martin P. Claussen, Historical Office, AAF Headquarters)

Brig. Gen. Franklin O. Carroll, Chief, Engineering Division, ATSC, 29 July 1945

Col. M. C. Demler, Assistant Chief, Development Engineering Branch, Materiel Division, M&S, 24 Nov. 1944

[redacted]

Maj. Gen. Oliver P. Echols, AC/AS Materiel and Services, 11 May 1945

R. R. Graichen, Principal Aeronautical Engineer, Office of AC/AS, M&S, Nov., Dec. 1944

Col. R. C. Wilson, Chief, Development Engineering Branch, Materiel Division, M&S, Nov. 1944

[redacted]

[redacted]

I N D E X

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

UNCLASSIFIED

[redacted]

[redacted]

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY AIR FORCES:
(Attention AAF Historical Office)

Subject: Critique of Army Air Forces Historical Studies: No. 50, Materiel Research and Development in the Army Air Arm, 1914-1945

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY AIR FORCES:
(Attention AAF Historical Office)

Subject: Critique of Army Air Forces Historical Studies: No. 50, Materiel Research and Development in the Army Air Arm, 1914-1945

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY AIR FORCES:
(Attention AAF Historical Office)

Subject: Critique of Army Air Forces Historical Studies: No. 50, Materiel Research and Development in the Army Air Arm, 1914-1945

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY AIR FORCES:
(Attention AAF Historical Office)

Subject: Critique of Army Air Forces Historical Studies: No. 50, Materiel Research and Development in the Army Air Arm, 1914-1945