MISSED OPPORTUNITIES:

NACA AND JET PROPULSION

by

Christian Claude NEGREL

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Arts

in

History

APPROVED:

Thomas R. DUNLAP, Chairman

David S. LUX

Burton I. KAUFMAN

April, 1989

Blacksburg, Virginia

MISSED OPPORTUNITIES:

NACA AND JET PROPULSION

by

Christian Claude NEGREL

Thomas R. DUNLAP, Chairman

History

(ABSTRACT)

This study examines NACA's organization in the light of Alfred D. Chandler's *Strategy and Structure.* It analyzes the agency's administration. NACA's strategy of maximizing existing technology and its committee's structure were the key elements in its failure to develop jet propulsion in the early 1940s. We will focus first on NACA and its organization. The second chapter will describe jet propulsion, particularly the acquisition of a Whittle engine from England and General Arnold's role in keeping NACA out of the development of the Whittle engine in the United States. The third chapter will concentrate on the reasons that combined and led to the difficulties of NACA in the mid-forties and the 1950s. That chapter will look at the rise of the aviation industry, the criticism it expressed against NACA, and finally NACA's strategy as one of the causes of failure.

Acknowledgements

I wish to thank my family for their support throughout all my school years.

I want to thank Dr. Thomas Dunlap and Dr. David Lux for their patient guidance of this project in the past two years. I am especially grateful for their thoughtful direction and their tireless efforts in supporting my work since I came to Virginia Tech. I also thank Dr. Burton Kaufman for his helpful suggestions and service on my graduate committee.

A special thank goes to of the Universite de Provence who helped me participate in this program, and encouraged me to come to the United States for a Master's.

I also want to thank my friends and for helping me accomplish the research necessary for the completion of this work, and for his insightful reading and suggestions.

Table of Contents

1.0 INTRODUCTION **1**

2.0 THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS (N.A.C.A.) .. **11**

2.1 BIRTH AND ORGANIZATION OF THE N.A.C.A. 12

2.1.1 CREATION 12

2.1.2 COMMITTEES 15

2.1.3 OFFICERS 18

2.1.4 FINANCES 19

2.2 NACA: THE ORGANIZER 24

2.2.1 NACA AND THE MILITARY 26

2.2.2 THE NACA AND THE AIRCRAFT INDUSTRY 29

2.2.3 THE POST AIR-COMMERCE ACT ERA 32

2.2.4 DEPENDENCE ON THE WIND TUNNEL 35

3.0 JET PROPULSION **37**

3.1 THE CONCEPT OF JET PROPULSION 37

3.2 EARLY WORK ON JET PROPULSION IN THE UNITED STATES 39

3.3 THE BRITISH ACHIEVEMENT 44
3.4 THE U.S. GETS A JET-ENGINE 48
3.5 CREATION OF A SUBCOMMITTEE ON JET PROPULSION 49
3.6 TRANSFERRING THE WHITTLE ENGINE 52

4.0 NACA AND JET PROPULSION 62
4.1 THE RISE OF THE INDUSTRY 62
4.2 CRITICISM OF NACA 72
4.2.1 LETTERS FROM THREE COMPANIES 72
4.2.2 HEARINGS 74
4.3 CHANDLER'S MODEL: A COMPLEMENTARY EXPLANATION 80

5.0 CONCLUSION 89

SELECTED BIBLIOGRAPHY 92
5.1 PRIMARY SOURCES: PUBLISHED DOCUMENTS 92
5.2 PRIMARY SOURCES: UNPUBLISHED DOCUMENTS AND LETTERS 93
5.2.1 NATIONAL ARCHIVES, MAIN BUILDING, WASHINGTON, D.C.: 93
5.2.1.1 RECORD GROUP 18 ENTRY 22 BOX 48 93
5.2.2 NATIONAL ARCHIVES RECORD CENTER, SUITLAND, MARYLAND 95
5.2.2.1 RECORD GROUP 255 GENERAL RECORDS (DECIMAL FILES) 621-623.1 95
5.2.2.2 RECORD GROUP 255 GENERAL RECORDS NASA-NACA GENERAL CORRESPONDENCE 1915-1942 NUMERIC FILE 21-22 TO 21-24 BOX 112 95
5.2.2.3 RECORD GROUP 255 RECORDS RELATING TO NACA COMMITTEES AND SUBCOMMITTEES 117.25 97

5.2.2.4 RECORD GROUP 255 RECORDS RELATION TO NACA COMMITTEES AND SUBCOMMITTEES 118.24-118.33 97
5.2.3 NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS 98
5.3 SECONDARY SOURCES 98
5.4 ARTICLES 100

Appendix A. THE WHITTLE ENGINE 101

Appendix B. LETTERS BY THREE MANUFACTURERS 153
B.1 BELL AIRCRAFT CORPORATION 153
B.2 DOUGLAS AIRCRAFT COMPANY, INC. 158
B.3 CONSOLIDATED VULTEE AIRCRAFT CORPORATION 162

List of Illustrations

Figure 1. GENERAL ORGANIZATION 16

Figure 2. YEARLY APPROPRIATIONS 1915-1958 21

Figure 3. YEARLY APPROPRIATIONS 1938-1946 22

Figure 4. YEARLY APPROPRIATIONS 1915-1935 23

1.0 INTRODUCTION

On October 1, 1958, the National Aeronautics and Space Administration (NASA) replaced the National Advisory Committee for Aeronautics (NACA). In order to understand this decision we must look at the events that shaped and influenced the creation and the existence of NACA. We do so here in context of Alfred Chandler's model that explained the success and struggle of large businesses. It is possible to apply his model to the history of science.

Congress had created NACA in 1915 to investigate the problems of flight, and for many years it remained the undisputed leader in aeronautical research, advising the military services and supporting the nascent aviation industry. In the 1920s it urged the U.S. government to support the new aircraft industry to compete with European countries, which financed the aviation companies. But in the United States, where a different ideology shaped business, government support had to take a different form than blatant government subsidies. The United States based its economy on private initiative and private enterprise and believed in non-intervention of the Federal Government in the affairs of private citizens. This ideology drove individuals to work and invest in the economic sectors that yielded most profits or that promised to yield most. The success of large companies substantiated the ideology, and strengthened the belief that government had to stay out of the sphere of business. This ideology led individuals to identify the Federal Government with bureaucracy, duplication of tasks, slowness and lack of efficiency.

The major reason for the creation of the industry in 1915 was the crucial role of aviation in Europe during World War I. Congress created NACA, a government agency, to keep up with the progress of the nations at war on the Old Continent because the industry could not assume that role. Yet, on one hand, NACA had to be aware of this distaste for government's involvement in the business world and on the other hand the fact that there was no private aeronautic industry in the first decade of the century. This shortage of manufacturers derived from the lack of market and the consequent lack of profits. No industrialist would take the risk to invest in an industry that would manufacture a product that nobody would buy.

The Advisory Committee, NACA's main committee, had to take these elements into account when defining NACA's goals. Until the late 1920s it maintained that the U.S. government had to support the new aeronautic industry until it could stand by itself. The Air Commerce Act in 1926 reduced NACA's commitment to the industry, nonetheless it kept working with both the industry and the military until 1958. The Committee concentrated on aerodynamics, structure of aircraft, materials, and other problems like de-icing or lightning hazards. In 1958 a major reorganization of the Committee's structure developed around space-oriented research, but by then it was too late.

Early in 1958 NACA also prepared the committee's version of a space agency, but the administration rejected it. The administration held at least three main reasons for dismissing NACA. The first reason was organizational; NACA had kept the same committee structure for forty-four years while both the staff and budget had sky-rocketed. In 1915 NACA listed one employee, by 1958 the Committee occupied over 8,000. The budget was $5,000 in 1915 and by 1958 the appropriations had grown to $101,000,000, and the administration considered that a committee might not be the best structure to run such a large budget. Furthermore, the Committee seemed too independent of the government. Considering why Congress created the Advisory Committee, the administration had some reason to think that the Committee's structure was not adequate, particularly in relation to development of jet propulsion and spaceflight.

Although the Eisenhower administration supported the "military industrial complex" the President frowned on it, and NACA fit the stereotype perfectly. The Advisory Committee had always put forward the military use of aviation, the role of aircraft in a modern defense and in combat. Besides, the Committee retained close links with the aeronautical industry, and the increase of membership in the postwar period gave the industry greater access to the committees and the Advisory Committee. In the mid-fifties Eisenhower wished to reduce the role of the Federal Government. He supported a sound economy and accordingly wished to slim down inflation and the deficit. NACA, with its million dollar budget was an obvious target. However, the administration's decisions to discard NACA was not so much the budget as the impression that NACA's strategy and structure were inefficient. The government terminated NACA, a civilian agency, and created NASA, another civilian agency with even larger budgets. This change might not have been necessary if the Eisenhower administration had identified NACA's failure as a problem of strategy rather than structure.

Finally, after the "Sputnik scare" Congress was ready to give the new space agency anything it required to catch up with the Soviet Union. If the administration had given the NACA the responsibility for the space program, it could predict very easily that the agency's budget would soar to unprecedented highs because of the ties between the services and NACA. In late 1957 and early 1958, the main fear of the military lay in the Russians' capability to lift heavy payloads in orbit or over intercontinental distances. The administration perceived that the military would quickly ask for enormous budgets to support research on large boosters, and the executive was not ready to allot this type of money to an independent agency.

Consequently, Eisenhower endorsed a civilian agency, which could not claim that its research would be essential to the military establishment, and the Federal Government would not have to finance the ever-increasing cost of missile and spaceflight research. Moreover, NACA's bad record with jet propulsion did not encourage further investment in the agency, and even encouraged planning for a new organization. In the framework that defined the role and activities of the Committee, spaceflight was the logical step in the development of aeronautics. NACA, however did not become the new space agency in 1958.

This study will focus on three essential elements: NACA and its organization, the development of jet propulsion, and the rise of the aviation industry in America. These are crucial because NACA had to face a challenge with jets, but the strategy of the organization caused it to ignore jet propulsion in favor of other problems. NACA's organization--its structure--played a key role here. The agency knew about jets, but stifled low level initiatives that might have led to research in the area.

It is necessary to describe NACA's organization in relation to Alfred D. Chandler's theories on the role of strategy and structure in organizational management. Chandler held that growth required a new structure. Enlarged businesses required changes at different levels, in the choice of executives, the design of new policy, and the change from the committee-managed department to the line-and-staff department. But before defining the areas where changes were necessary Chandler identified the essential parts of a business, the administration and its functions, and the form of organization which resulted from strategy. The strategy is the determination of the long-term goals of the enterprise, and the adoption of the policy necessary to achieve these goals. NACA's strategy was to create a strong aviation industry, and solve fundamental problems, and it succeeded in the 1920s and early 1930s. But it did not take the steps to move to the fields that were becoming essential to aeronautics.

Moreover, NACA's strategy was to keep the industry out of the Advisory Committee. It succeeded until 1945, but at the cost of alienating a now-powerful industry. Although Chandler's theory related to the growth of organization it helps to understand the relation of the agency with external identities. After studying the interaction between NACA, the military, and the industry it appears that NACA failed to realize that its support to the private industry was a success. The industry had become a giant, but the agency did not apprehend the situation. It did not change its relation to the industry, and kept it out of the most important committees. In the meantime, the military became aware of this change and modified their external relations both to the industry and NACA. The services, and particularly General Arnold, perceived that the aviation industry could accomplish the work that only NACA had previously been able to perform. Accordingly, the military changed their strategy and especially their relation to the industry. NACA's strategy of keeping the industry out of the committee is certainly the basis of the fundamental change in relation that occurred between the military and NACA on one hand, and the military and the industry on the other. In order to understand better where things did not go well we must describe the organization of NACA, its creation by Congress in 1915, its goals of the Committee, and functions and status conferred by law. The study must also identify the source(s) of income, and the amounts of money that the Committee spent and the chains of command, the officers, the work of major committees, the executives who established the research thrusts and the allocation of funds.

The chapter's second part describes NACA's work at different levels, its advisory and organizational functions up to 1926, the relationship of the agency to the military and the industry, and the important change that took place in the late 1920s and 1930s. In the first fifteen years, the NACA advised the government on aviation policy and conducted basic research on the problems of flight. The Air Commerce Act of 1926 relieved the Committee of all administrative tasks and allowed it to concentrate on what the Main Committee considered its principal task, the conduct of fundamental research on the problems of flight. By that time the industry was growing and did not need so much the support of NACA. In 1928 the Collier trophy crowned the agency's work. The prestige of winning that trophy galvanized the Committee to intensify research in aerodynamics. This absorbed most of the funds and "energy" of the Committee. As the Committee focused the research, the laboratories could not obtain outstanding results in all the fields of aeronautics that required investigation. This change finally harmed the Committee's ability to meet new challenges and its image.

Undoubtedly, one of the most interesting events in the history of the development of jet engines in America was the technology transfer involved in the military's acquisition of the British Whittle engine. It provided the basis of jet propulsion, and neither NACA nor the industry achieved such results. Secondly, it is essential to concentrate on the British achievement because the U.S. Army Air Corps secured one Whittle engine and could then start duplicating it in the United States. Whittle's study of jet propulsion began in the 1920s and in early 1941 he began test flying an aircraft with a jet engine, the Gloster E28/39. A few months later the British Air Ministry released to the U.S. Army Air Forces two Whittle engines and drawings, in addition the British authorities sent two technicians to the United States to help begin production. The acquisition of the Whittle engine by the services was not only crucial for the military establishment, but also for NACA.

Those few months played a decisive part in the survival of NACA after 1958. General Arnold's decision to keep NACA out of the work on the Whittle engine affected the credibility of the Committee. If one considers that NACA possessed the theoretical knowledge to undertake a serious study of jet propulsion, one must ask why the Committee did not work on it. Those events are fundamental in the history of the Committee because they ultimately put and end to the existence of the agency. Until now there has been no detailed account of what happened between Britain, the head of the Army Air Forces, General Henry H. Arnold, and the Advisory Committee. Many, if not all, students of jet propulsion or NACA, neglected the process through which the Army acquired the engine, and the way General Arnold discarded NACA. In the early 1940s the Advisory Committee lost some of its prestige, with the services by lagging behind the British and the German in the development of jet propulsion. The industry began criticizing its operations. Yet, if the industry could present its views so strongly it was because it had grown since the time when NACA used to support it.

The last chapter treats the rise of the aeronautics industry in America, the industry protest against NACA, and places NACA's difficulties with jets and the loss of influence that it suffered in the perspective of Chandler's *Strategy and Structure.* The rise of the aviation industry is crucial. The industry benefited from NACA's support at a time when it industry mainly produced and sold aircraft. But later on, when the Government decided to give large contracts to ensure the development of a large military fleet, the industry started developing its own research centers and did not need NACA as much as it had. Moreover, the complex relationship that existed between NACA, the industry, and the military services put a strain on the agency. Chandler described more than the development of large businesses; he studied the transformation and struggle the companies had to go through in order to survive and face competition. This model can be used in other areas than large corporations and business, in fact it works with any large bureaucratic agency.

The military services relied on NACA for advice on new aeronautic technologies and on the industry to fill their orders. Under the industry's recommendation the military ordered NACA to work on specific problems involving basic research. But the industry was dissatisfied by NACA's insistence that the manufacturers not serve on the Advisory Committee and Executive Committee. This situation brought industry complaints, and raised suspicions about the Committee's work. NACA's dismissal of jet propulsion gave manufacturers the force to protest NACA's policies. At the end of the war a Senate Special Subcommittee investigated the national defense program, and held hearings on NACA. The hearing pointed to the Committee as the major cause for the U.S. lag in propulsion.

NACA was not an industrial enterprise, at least in the sense that it did not engage in development of prototype or mass production. Yet it had customers, mainly the military, which provided the principal source of revenue for the committee. NACA had different branches and departments like any large business, and by keeping its customers happy got larger appropriations. The number of its employees kept growing until it reached a total of 8,000 by 1958.[1]

Chandler's study explains how large companies struggle towards success, but his approach also identifies the reasons why the companies that do not go through the same steps face difficulties or even disappear. The general conclusion of this model is that change is in the hands of the executives of the company, and only they, provide the impetus necessary to expand in new fields, and ensure the survival of the company. NACA needed a new strategy that would enhance the structure needed to achieve the goals of the agency. The Committee's strategy did not look far enough and neglected to see jet propulsion as the essential component of the new generation of aircraft.

---

[1] Hence for the sake of simplicity this study will refer to NACA as a "business."

2.0 THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS (N.A.C.A.)

Understanding NACA and the work that the Committee undertook requires knowledge of the circumstances that led to the creation and the organization of the Committee. The administration of NACA, and its success in the late 1920s and early 1930s, are important, but we must also look at that period as a decisive turning point.

2.1 *BIRTH AND ORGANIZATION OF THE N.A.C.A.*

2.1.1 CREATION

In an attempt to catch up with European nations the United States created an aeronautic agency, the National Advisory Committee for Aeronautics (NACA). NACA was a governmental agency, but this chapter will demonstrate the independence Congress gave to the Committee. On March 3, 1915, following the lead established by the British a few years earlier, Congress approved the creation of the National Advisory Committee for Aeronautics, to "supervise and direct the scientific study of the problems of flight, with a view to their practical solution."[1] The English and American decisions reflected the concern of industrialized nations about aviation.

Since the beginning of the century, the problem of flight had preoccupied France, Germany and Britain. On July 25, 1909, Louis Bleriot flew across the English Channel, and for the first time Britain could fear an invasion from the continent by unconventional ways. Although the creation of the British Committee and Bleriot's flight had no connection, they revealed the rapid

1 *U.S. Statutes at Large,* (Public Law, No.271, 63rd Cong.)

advance of the new technology and its impact on both the popular mind and institutions.

Public Law 271, creating NACA, authorized the President of the United States to appoint twelve people, who would serve without compensation.[2] The President was to choose two from the War Department, two from the Navy, one each of the Smithsonian Institution, the Weather Bureau, and the Bureau of Standards.[3] He could appoint five additional members who had to "be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences."[4] These twelve formed the Advisory Committee, which elected a smaller committee, the Executive Committee, which in turn created subcommittees and special committees to study different problems, allocated funds, and decided the termination of the committees.[5]

The act created NACA to advise the nation on its national aeronautical program, but it also included a provision that would eventually allow the committee to conduct experiments in laboratories. The committee would have the authority to "determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions." This

---

2 In this study the words "the Committee" or the "Main Committee" will refer to the Advisory Committee.

3 The act did not specify the mandate of the members but they served for five years.

4 Public Law, No. 271

5 Congress increased the membership of the Advisory Committee to fifteen members in 1929 and seventeen in 1948.

statement implied that NACA had to be constantly aware of all the developments in aeronautics and of the new research it required.

The law that established NACA made it very independent. It was responsible only to the President and could formulate its own rules and regulations. At the first meeting, on April 23, 1915, the members of the Advisory Committee established a set of Rules and a set of Regulations. The five articles dealt with the appointment of officers and members of the different committees, the finances, and the frequency of meetings. The Rules provided the guidelines for the Committee to exercise the functions authorized by the Act. On June 14 President Wilson approved those rules. The Committee was solely responsible for its organization and the conduct of research and could amend the rules. The Advisory Committee had the power to change the rules and the structure of NACA and as problems arose over the years the Committee amended the original rules slightly, but it did not make major changes.[6]

The Advisory Committee created the Rules to outline the functions of NACA. The Committee could advise or do research for the military, for the civil agencies of the US Government, indeed for "any individual, firm, association, or corporation within the United States," as long as the customer financed the actual cost of research.[7] However, the Committee made it clear that the laboratories would not expend any fund on the development of inventions, or on

---

6 This section compares the initial rules with the 1949 version. It is not a study step by step of all the amendments.

7 *First Annual Report: 1915*, NACA, 10.

experimenting with inventions for the benefit of individuals or corporations.[8] The regulations described NACA's administration, frequency of meetings, the operation of committees, the officers of the Committee, and finances.[9] The Advisory Committee met twice a year, an "annual meeting" in October, a "semiannual" one in April, and could meet at other times to solve particular questions.[10] After any meeting the Advisory Committee had to issue a draft of the minutes, and send a copy to each member for approval. Rules and Regulations centralized power in the hands of a few members. This was a double-edged sword since it could enhance or inhibit the study of new problems. Such concentration of power furnished a key element in the structure of NACA and its Committees.

2.1.2 COMMITTEES

The Advisory Committee, the Executive Committee, and the different committees and subcommittees formed NACA's basic structure.[11]

---

8 In 1949 the Rules included a new paragraph (4) that allowed the Advisory Committee to make recommendations to the Patents and Design Board about aeronautical inventions and designs.

9 Article III of the Regulations allowed the Executive Committee to collect and issue aeronautical information. This article did not seem very important in the early stage of NACA, but it played an important role in 1946 when a Special Subcommittee of the Senate Armed Services investigated the work of NACA on jet propulsion.

10 The dates of annual and semiannual meetings changed over the years as to facilitate attendance by the different members. The procedure to call for those special meetings differed slightly over the years. In 1915 the Executive Committee or the written request of five members of the Advisory Committee could call special meetings. After 1949 only the Chairman or five members of the Advisory Committee could call special meetings.

11 NACA had a very particular way to name its subcommittees, and Alex Roland declared in his study that the Committee was not very consistent in the naming of the committees. As a general rule all the committees that were not standing committees were called subcommittees.

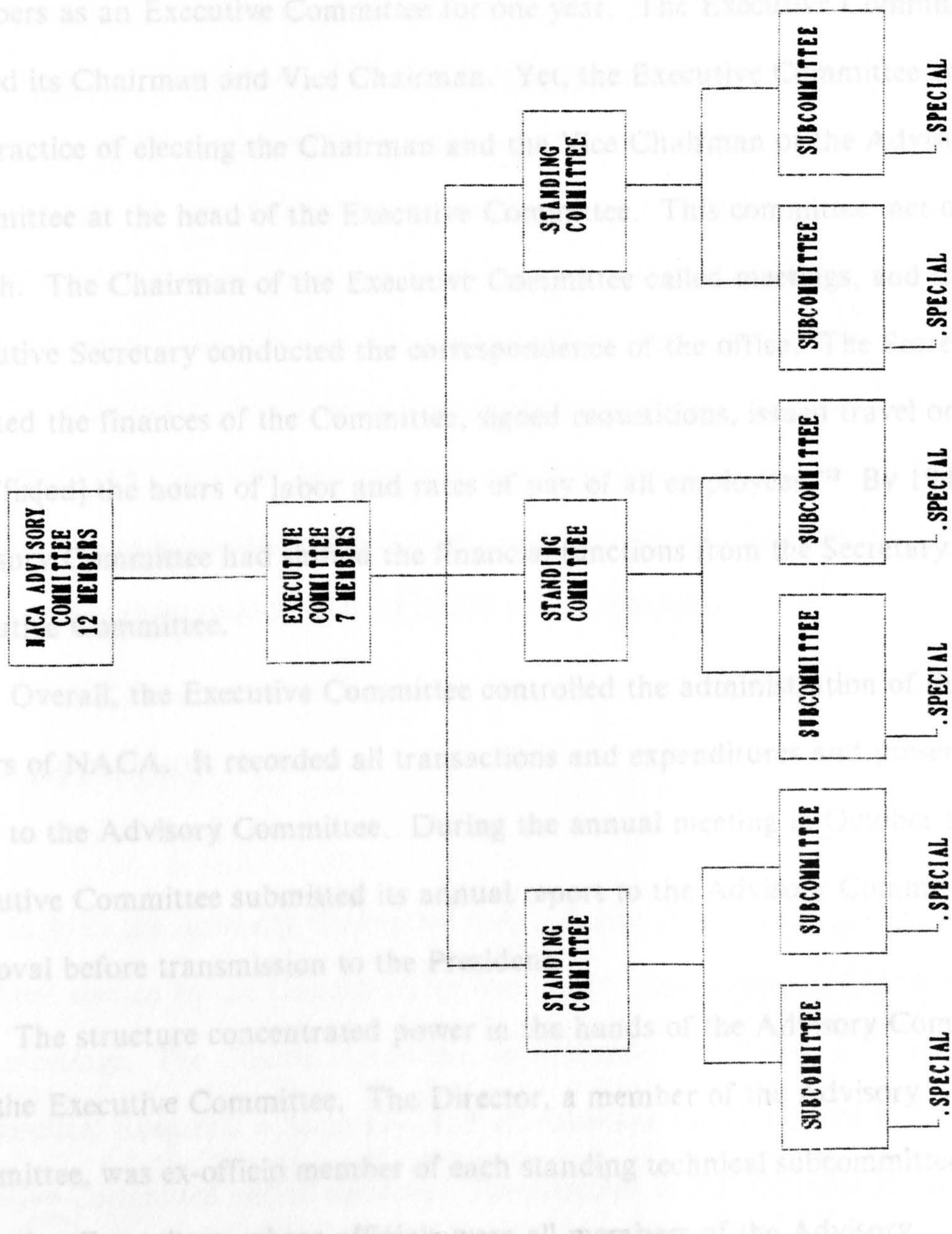

Figure 1. GENERAL ORGANIZATION

The President of the United States nominated the twelve members of the Advisory Committee. In turn, the Advisory Committee chose seven of their members as an Executive Committee for one year. The Executive Committee elected its Chairman and Vice Chairman. Yet, the Executive Committee got into the practice of electing the Chairman and the Vice Chairman of the Advisory Committee at the head of the Executive Committee. This committee met once a month. The Chairman of the Executive Committee called meetings, and the Executive Secretary conducted the correspondence of the office. The Secretary directed the finances of the Committee, signed requisitions, issued travel orders, and "fix[ed] the hours of labor and rates of pay of all employees."[12] By 1949 the Advisory Committee had shifted the financial functions from the Secretary to the Executive Committee.

Overall, the Executive Committee controlled the administration of the affairs of NACA. It recorded all transactions and expenditures and presented them to the Advisory Committee. During the annual meeting in October the Executive Committee submitted its annual report to the Advisory Committee for approval before transmission to the President.

The structure concentrated power in the hands of the Advisory Committee and the Executive Committee. The Director, a member of the Advisory Committee, was ex-officio member of each standing technical subcommittee. The Executive Committee, whose officials were all members of the Advisory Committee, appointed standing committees, and special committees, and

---

[12] *Model Research*, 416.

subcommittees, and it decided which problems to study. Generally, the Executive Committee would disband the committees once they had solved the problem. Furthermore, the Chairman of these standing committees had to be a member of the Advisory Committee. This structure gave great power to the Advisory Committee, which controlled every single standing committee or technical subcommittee. It provided coherence and harmony among the members which was undoubtedly one of the strengths of the Committee in its earlier years, but prevented creative input by the different members of each committee.

In that growing organization the number of officers working at NACA was surprisingly low. In 1920, headquarters employed thirty-six persons, and eighty by 1941. In the same period, the number of field employees went from sixty-three to 797, and appropriations from $175,000 to $11,200,000.

2.1.3 OFFICERS

In 1915 the Advisory Committee only had two officers, a Chairman and a Secretary, elected by the Committee for one year.[13] The Chairman had to preside at all meetings. The Chairman had the responsibility of choosing a Director of Aeronautical Research, a Secretary, and an Assistant Secretary, which the Executive Committee had to approve. The Director of Aeronautical Research executed the policies of the Committee.[14] He prepared programs "for the

[13] By 1949 their titles had changed to the Chairman and Vice Chairman.

[14] His title later changed to "Director."

allocation and coordination of scientific research in aeronautics," directed research at the laboratories and was an ex-officio member of each standing technical subcommittee.[15] His duties included correspondence and the preparation of an annual report on the technical activities of the Committee. The Secretary issued notices of meetings of the Advisory Committee, recorded its transactions, and conducted the correspondence relating to the Committee. He was ex-officio Secretary of the Executive Committee. He directed the administrative work of the Committee and generally supervised the expenditure of funds and the employment of NACA's personnel.[16]

2.1.4 FINANCES

The evolution of the budget is a reasonable indicator of the growth of the agency. In 1915 Congress appropriated the sum of $5,000 a year for five years for "experimental work, investigation,... clerical expenses, [ ] supplies," and traveling expenses for the members of the Committee attending the meeting. Congress provided the largest part of NACA's finances between 1915 and 1958.[17] The Committee's fiscal year began on the 1st of July of each year. At the

[15] Alex Roland, *Model Research: The National Advisory Committee for Aeronautics 1915-1958* (Washington, D.C.: National Aeronautics and Space Administration, 1985), Vol 2., 416.

[16] In 1949 his task as assistant head of the agency was to direct NACA's administrative work.

[17] The Committee may have received funds from customers for which it undertook investigations, but there is no record available to confirm this source of funds, if it exists it was probably negligible.

annual meeting of the Advisory Committee the Executive Committee presented a detailed report of NACA's activities and the budget for the following year.

Wars played an important role in NACA's history. World War I made apparent the weaknesses of American aeronautics and spurred the creation of NACA. During the war the United States realized that airpower had become essential both to the defense of U.S. territory. It was needed to insure the independence of the Allied nations. The hostilities in Europe strengthened the need for an agency such as NACA, and the Committee's budget reflected this trend. Appropriations went from $5,000 in 1916 to $87,515 in 1917; an increase of 1650.3%. Between 1917 and 1918 the appropriations went up by 27%, and by 1919 appropriations had leaped another 83.03%. The Second World War had a similar effect. Between 1938 and 1945 appropriations grew at an annual average rate of 78.65%. They grew by 217% between 1938 and 1939, and by 167% between 1940 and 1941. The Korean War and Sputnik duplicated that situation. Although the Independent Offices Appropriation Act, enacted on August 24, 1949, had included an increase of 8.9% for 1950 the sum went up by 163%. In June 1950 North Korea invaded South Korea and on June 29, 1950, Congress passed the Deficiency Appropriation Act (Public Law 583, 80-2) that increased NACA's appropriation by $75,000,000.

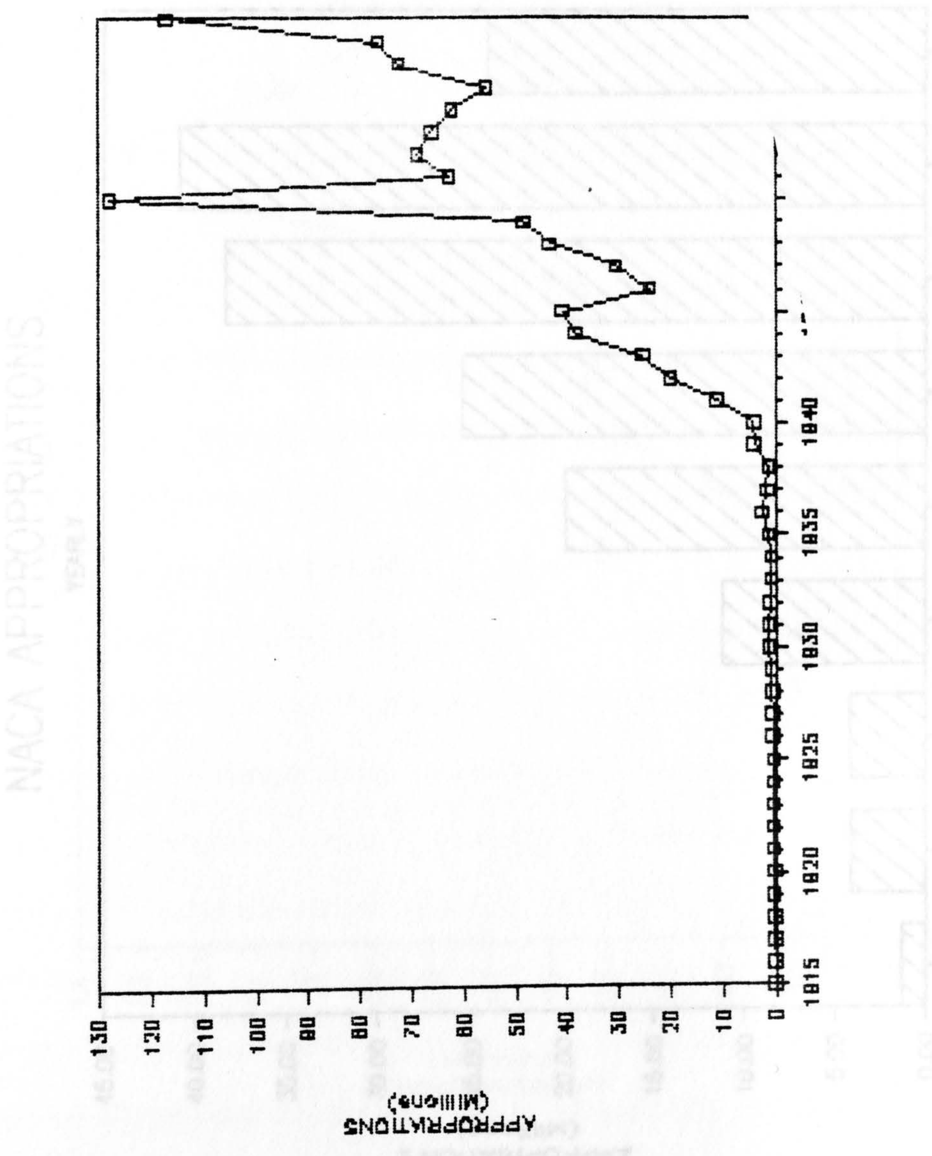

Figure 2. YEARLY APPROPRIATIONS 1915-1958

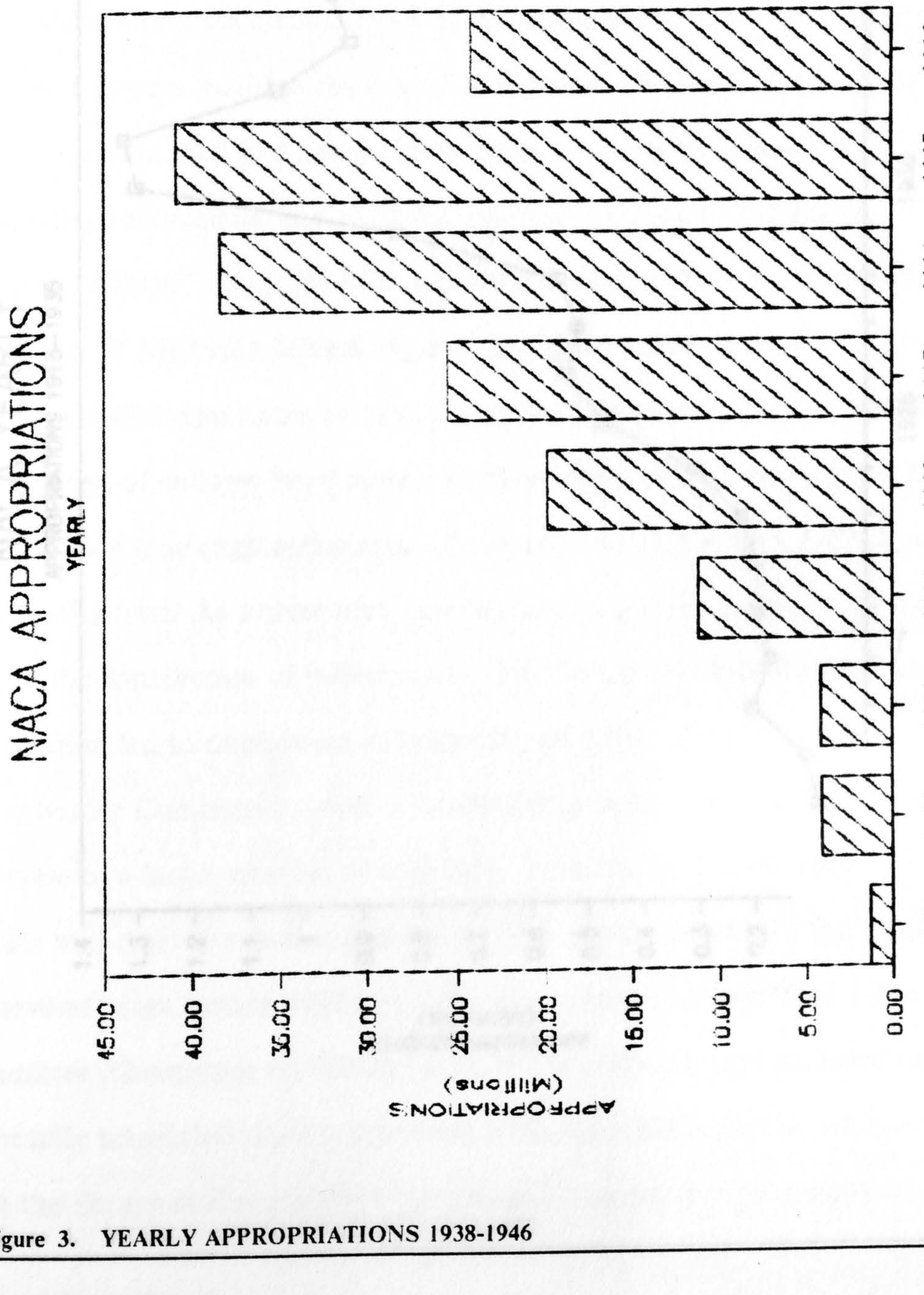

Figure 3. YEARLY APPROPRIATIONS 1938-1946

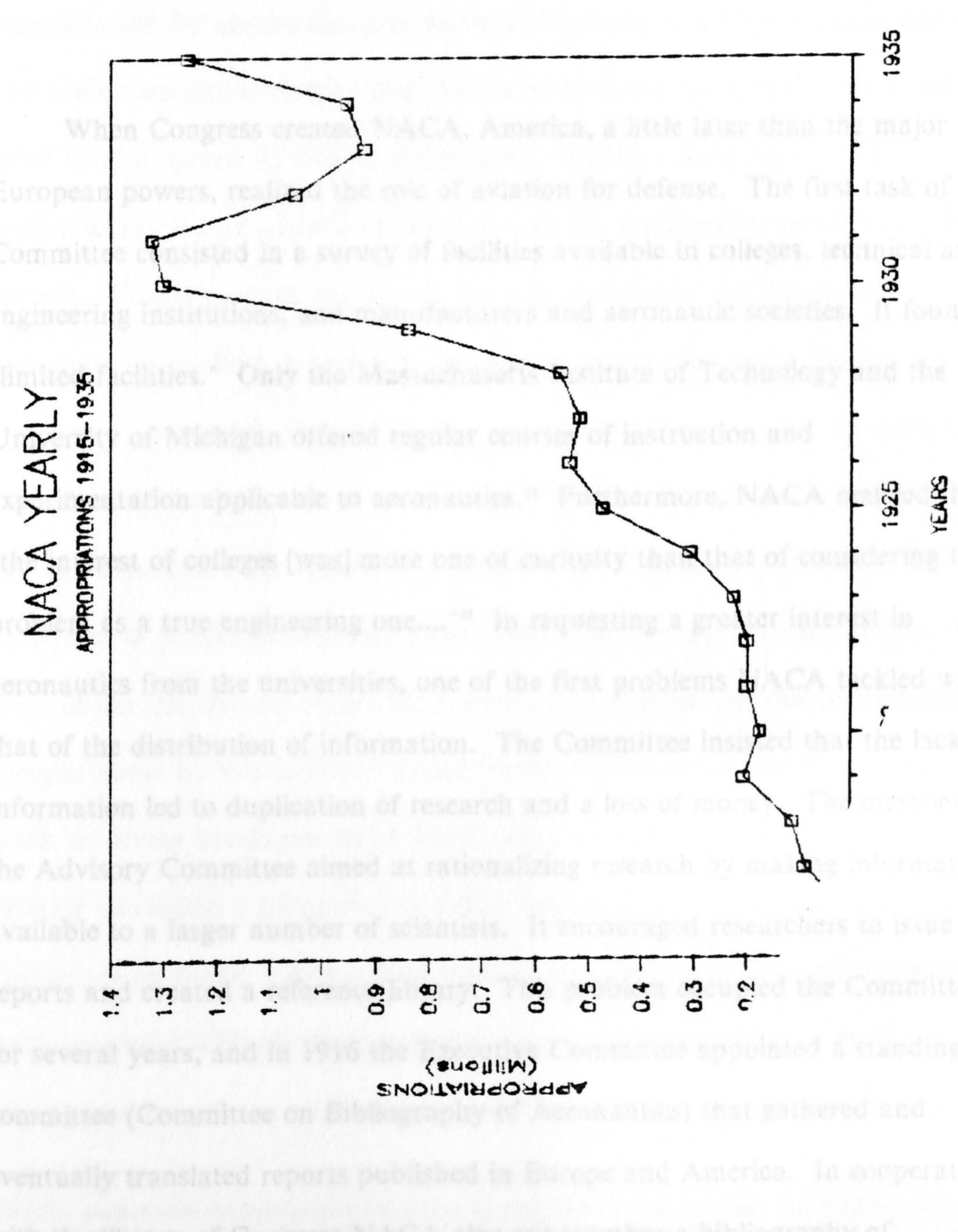

Figure 4. YEARLY APPROPRIATIONS 1915-1935

2.2 *NACA: THE ORGANIZER*

When Congress created NACA, America, a little later than the major European powers, realized the role of aviation for defense. The first task of the Committee consisted in a survey of facilities available in colleges, technical and engineering institutions, and manufacturers and aeronautic societies. It found "limited facilities." Only the Massachusetts Institute of Technology and the University of Michigan offered regular courses of instruction and experimentation applicable to aeronautics.[18] Furthermore, NACA realized that "the interest of colleges [was] more one of curiosity than that of considering the problem as a true engineering one...."[19] In requesting a greater interest in aeronautics from the universities, one of the first problems NACA tackled was that of the distribution of information. The Committee insisted that the lack of information led to duplication of research and a loss of money. The members of the Advisory Committee aimed at rationalizing research by making information available to a larger number of scientists. It encouraged researchers to issue reports and created a reference library. This problem occupied the Committee for several years, and in 1916 the Executive Committee appointed a standing committee (Committee on Bibliography of Aeronautics) that gathered and eventually translated reports published in Europe and America. In cooperation with the library of Congress NACA also put together a bibliography of

---

[18] *Annual Report 1915*, 12.

[19] Annual Report 1915, 13.

aeronautics. The Committee on Bibliography of Aeronautics produced a nomenclature for aeronautics and worked effectively to define technical terms. The Main Committee insisted that the industry would not achieve any significant result until it agreed on common standards. Hence, NACA took the lead and studied airplane instruments, accessories, and the standardization of materials for aircraft. Gathering data was one of the main tasks that the Committee undertook in an effort to organize the field of aeronautics in the United States, and it was a success.[20] In the following years, NACA emphasized the need for a unification of the field, and stressed the need for standardization of nomenclature and specifications. The members of the Advisory Committee advocated the enactment of legislation regulating the "design and operation of aeroplanes."[21]

In the first annual report the Committee predicted that the development brought about by World War I would "rapidly force aeronautics into commercial fields, involving developments of which today we barely dream."[22] Hence, it strongly advocated a governmental policy and guidelines for aeronautics. The Committee produced a tremendous work to organize a new field, and presented the government with all the aspects that requested investigation or research. It tried to convince the government that the United States needed a military air

---

20 NACA worked with the Smithsonian Institution, and particularly Paul Brockett, who published a book on the period up to 1910. The Committee prepared a bibliography of aeronautics from 1910 to 1916 (in two volumes), and a one-volume bibliography for 1917 and 1918. NACA's policy included the publication of a yearly bibliography from 1918 on.

21 Annual Report 1915, 17.

22 Annual Report 1915, 20.

fleet, but also a strong aviation industry, and insisted that legislation was the best way to achieve a stable and efficient industry.

The work of the Committee included routine administrative tasks. The members of NACA considered ground schools for aviators and insurance. They encouraged legislation to regulate civil aerial navigation, the issuance of licenses to pilots, the inspection of aircraft, and uses of landing fields. One of NACA's main concerns was safety. In its first decade the Committee insisted that the industry would not become self-sustaining until safety problems had been solved. NACA considered it its task to investigate and improve safety through the scientific study of flight. The results would benefit both the military services and civil aeronautics. Thus, the Advisory Committee proposed and then created a committee to investigate airplane accidents and the study of the atmosphere in relation to aeronautics. If the investigation of accidents could reveal the causes, the Committee could then attack the problems. The study of the atmosphere would help increase safety and economy. For the same reason NACA also developed aerial photography and mapping to help aviators.

2.2.1 NACA AND THE MILITARY

From its creation the agency cooperated with the military services, coordinated scientific and research work between the Navy, the Army, the government agencies, and the Committee, and acted as an advisory body for the military, which had to deal with new concepts and a new technology that involved more and more scientific work. The military depended heavily on NACA's comments and benefited from its work.

In the 1915-1926 period the Committee successfully developed an argument that convinced Congress to fund the aviation industry through the military. Between 1914 and 1918 the nations at war in Europe used airplanes for the first time, and NACA perceived aviation primarily as a sophisticated weapon. Throughout that twelve-year period NACA amplified the role of military aviation. Between 1915 and 1918 the Committee discussed aviation as a possibility for defense. From 1919 onwards NACA stressed that aviation would be "the first arm of offense and defense to come into action in future wars."[23] By the mid-twenties the Committee maintained that aircraft "[were] absolutely necessary for mobile coast defense...."[24] and that aviation was "a weapon indispensable to war operation."[25] In order to support this argument the Committee equated supremacy in the air and superiority in the outcome of combats. In 1920 NACA emphasized that the United States should learn a lesson from World War I and advised preparedness, which meant the maintenance of an aircraft industry and trained personnel. According to the Committee the government should aim at creating a self-reliant military force in time of war. In 1923 the navy won the Schneider Cup in an international competition for seaplanes and established the new official world's airplane speed record (243.67 mph), while the Army Air Service completed a nonstop coast to

---

[23] Annual Report 1919, 39.

[24] Annual Report 1923, 56.

[25] Annual Report 1925, 59.

coast flight in 27 hours. On the basis of those achievements NACA could intensify its request for Congress to support military aviation through increased appropriations.

Quickly the Advisory Committee realized that NACA, the military services and the industry had common interests, and at least some part of each organization's structure could combine with one or several sections of the others. Edward W. Constant refers to this concept as "interface requirements."[26] He explains that:

> Each community or subcommunity of practitioners is pretty much free to pursue its own ends, provided essential interface requirements are met: provided the cost and performance boundary conditions set by the expectations of other communities concerned with other aspects of the same overall system are not violated.[27]

From 1915 to 1940-41, NACA's main "interface" with the military was in the improvement of aircraft, which the Committee accomplished through fundamental research. NACA matched the expectations of the services but did not satisfy completely the industry's, and manufacturers wanted larger access to the committees. The industry's opinion did not affect NACA until the question of jet propulsion changed the military's expectations. The services expected the industry, and above all NACA, to develop jet propulsion. The services' request for jet engines did not leave the industry, or NACA, free to pursue their own ends. Under the pressure of the military NACA created a Special Committee on jet propulsion, and the industry began working on jet engines.

---

[26] Edward W. Constant II. *The Origins of the Turbojet Revolution* (Baltimore: The Johns Hopkins University Press, 1980), 11.

[27] Constant, 11.

In 1920 the Committee urged the Federal Government to encourage the development of aviation by funding the Army and the Navy. These agencies would in turn acquire aircraft and maintain a nucleus of aircraft industry that would quickly shift to wartime production. By 1925 NACA reported that the industry had improved greatly because the volume of military appropriations had increased. Larger budgets allowed the services to order a greater quantity of aircraft. The Committee pointed out that the betterment of the industry helped commercial aviation by lowering the costs and increasing safety.

2.2.2 THE NACA AND THE AIRCRAFT INDUSTRY

As early as 1915, NACA predicted a bright future for the aviation industry. Yet, the Committee realized that the key of success laid in governmental support. NACA worked in two directions to convince the government of the necessities of an aeronautical industry. First, it justified support for the industry on both economic and military basis. Secondly, it kept requesting the creation of a Bureau of Aeronautics under the Department of Commerce. NACA stressed that the United States must use the lessons of the war. In 1915 America had embarked on a crash program to catch up with European powers, but the Committee concluded that this "forced development" could not provide efficient results in the future. The only alternative lay in the maintenance of a stable aviation industry. In an emergency, the industry could quickly shift to wartime production. As a comparison the Committee cited the automobile industry.

Furthermore, a sound aeronautic industry could emphasize research and training while enhancing scientific and technical knowledge. In the 1919 *Annual Report* NACA identified the lack of scientific research and training as the major cause of delays during the war. In the early 1920s it also insisted on the inferiority of the United States' aeronautics industry to Europe's.

The Committee encouraged Congress to support military and commercial aviation to stay abreast of and compete with European nations. NACA struck a very sensitive chord with this argument because the United States, even more than other nations, took drastic steps to avoid being second best at anything. Moreover, America ran the risk of losing benefits gained during the war. In 1920 NACA analyzed the legacy of the war, reviewed the state of the industry, and declared that in 1918 the industry was at the stage of quantity production. America possessed a large amount of aircraft material, a large number of trained flyers and a few scattered fields. Yet between 1918 and 1920, the advance acquired through forced development quickly crumbled away, aircraft material became obsolete, a majority of technical personnel and trained flyers returned to private life, the aircraft industry almost disappeared, and the local authorities abandoned some of the landing fields.

The situation did not improve. In 1923 the Committee explained the poor state of commercial aircraft industry by the fact that "there [had]... been but little application of existing knowledge of aircraft, or air navigation, to commercial purposes."[28] NACA added that there existed two other reasons for the lack of

[28] Annual Report 1923, 55.

commercial flying: reliable service at reasonable cost, and the lack of Federal and State legislation encouraging the development of commercial aviation. The only way to help the industry was to lower costs and increase safety, and until a strong, self-supporting aircraft industry developed, NACA urged Congress to nurture it.

Soon after 1915 the Committee realized how widely the field of aeronautics extended. Until 1926 NACA called for the creation of a Bureau of Aeronautics under the Department of Commerce because the agency perceived the need for regulation and organization of civil aviation. The request for the enactment of Federal legislation appeared every year in the *Annual Report*. In 1922 NACA, declared that Federal legislation "[was] not only desirable but essential if America, the birthplace of aviation, [was] to become foremost in its development."[29] Finally, in 1926 Congress enacted the Air Commerce Act under which the Secretary of Commerce would "establish airways and emergency landing fields, inspect and register aircraft and facilities, and examine and license airmen."[30] According to the Committee, the Act established commercial aviation on a sound basis and gave it an important measure of stability. The Air Commerce Act liberated NACA from heavy administrative tasks and left the agency free to direct its attention to the scientific study of flight for the benefit of civil and military aeronautics. The law turned out to be crucial to the future of NACA.

---

[29] Annual Report 1922, 51.
[30] Annual Report 1926, 66.

2.2.3 THE POST AIR-COMMERCE ACT ERA

After 1926 the Committee spent most of its energy in the scientific study of flight, abandoning its advisory mission to the Department of Commerce. Between the 1915 and 1957 NACA centered its research around four major committees: Aerodynamics, Power Plants, Aircraft Construction, and Aircraft Structures. This strategy hardly changed between 1915 and 1958. NACA created *ad hoc* committees to answer particular questions and dismissed them when they submitted their final reports.

The events that took place in late 1957 (Sputnik 1 and 2) prompted a major reorganization of committee structure. The Advisory Committee added the words "Aircraft, Missiles and Spacecraft" to the major committees.[31] It also created a special Committee on Space Technology.[32] But by that time, criticism of NACA ran high and President Eisenhower's reorganization of the U.S. space program discarded NACA's option, creating in its place the National Aeronautics and Space Administration.

Although there are several reasons why NACA disappeared, all go back to the Advisory Committee's action (and lack of action) in the matter of jet propulsion, which must be seen in terms of NACA strategy and structure and in relation to other aeronautical organizations. As will appear later, NACA had the knowledge to undertake the study of jets, but the final decision belonged to the

[31] See charts

[32] The Stever Committee investigated Space Research Objectives; Vehicular Program, Reentry; Range; Launch and Tracking facilities; Instrumentation; Space Surveillance: Human factor and training.

Executive Committee. This will be the subject of the last part of the study. First, it is necessary to describe NACA's attitude towards research, and its relationship to the industry and the services.

In its reports to Congress the Committee consistently stressed that aviation required the scientific study of the problems of flight. Yet this stress on theory and scientific study pushed NACA into a blind alley. The Committee praised itself for achievements in basic research, such as in aerodynamics, but refused to undertake development of aircraft. It looked down on experiment and the kind of work that the industry accomplished. This attitude would play a key role for its future. NACA had different interests than the organizations it worked with; the Committee stressed fundamental research while the military and the industry favored results.

The military benefited from the applications of science and technology to aviation. For the first time in military history the services had the opportunity to observe, fight, and defeat the enemy from the air. At first their interest focused on flying and the ability to bomb or fight. Quickly, however, the military services put more and more emphasis on speed and performances. They wanted the state of the art, and pushed for continuous improvements in aerodynamics, propulsion, structures, or bombing techniques.[33] The services expected NACA to develop or *at least* to advise them on cutting-edge techniques (or arms) that aeronautics produced. The industry's goals were rather different from those of NACA, and only incidentally similar to the military's. Before World War I the

---

[33] Many of the wartime reports dealt with bombing techniques and blast effects.

industry simply produced aircraft and sold them. The aeronautic "industry" was born with World War I. During a five year period the industry went from non-existence to mass production for the military.

But this aeronautic industry, like any other industry, sought profit. Profit ensured survival and constituted the essence of its existence. Competitiveness was, and still is, the industry's main incentive to change. A manufacturer has to concentrate on what its customers want. Airlines will aim at security and economy of operation and maintenance, but the military services will prefer performances and innovations. One example is Douglas aircraft and the DC-3. Douglas developed the DC-3 from the DC-2, a fourteen-passenger airplane. The new aircraft seated 21 passengers, and became the "airplane capable of supporting itself economically as well as aerodynamically."[34] In two years the DC-3 carried 95% of America's civil air traffic. The success of the DC-3 also affected the military. In 1936, the twin-engined B-18 bomber replaced the B-10. The DC-3 had provided the basis for the new bomber.

A firm must invest large amounts of money in building a plant, acquiring the tools and training workers to produce a particular piece of hardware. It cannot afford to make drastic changes once a customer places quantity orders. Changes delay production, increase costs and greatly lower productivity. This strategy also applies to the aircraft industry. The manufacturer will improve a product and make it last as long as possible. Yet he will be careful to remain open to services' suggestions and requests. Basically NACA, the military

---

[34] Rae, John Bell, *Climb to Greatness: The American Aircraft Industry, 1920-1960*, Cambridge, Mass.: The M.I.T Press, 1968, 71.

services, and the industry had very different goals; respectively research, performances and innovation, profit and satisfying its customers. The military's needs changed rapidly, the industry followed, but NACA did not. It aimed at studying the problems of flight by pinpointing a few areas of research like aerodynamics. The best illustration of this is NACA's use of the wind tunnel.

2.2.4 DEPENDENCE ON THE WIND TUNNEL

In the first half of the twentieth century the speed of aircraft increased dramatically. NACA considered that improving aerodynamics was one of the most efficient ways to achieve greater speeds and it emphasized wind tunnel work and research.

In order to investigate the problems of flight NACA established four centers, the Ames Aeronautical Laboratory at Moffet Field, California; the Langley Aeronautical Laboratory, Langley Field, Virginia; the High Speed Flight Test Center, Edwards Air Force Base, Muroc, California; and the Lewis Flight Propulsion Laboratory, Cleveland, Ohio. Langley the oldest and largest concentrated on aerodynamics, aircraft structures, hydrodynamics and rotary-wind aircraft. In 1955 it had twenty wind-tunnels producing speeds from subsonic to transonic, and from supersonic to hypersonic speed. Ames worked primarily on aerodynamics and by the midfifties it operated three wind tunnels, one of which was the largest in the world--40 feet by 80 feet. Engineers at the Flight Propulsion Laboratory studied methods of propulsion and could simulate high altitude to investigate engines under all conditions. It also operated six small wind tunnels for aerodynamics research. NACA funded its success on the wind tunnel technology, and the laboratories produced wing design that even today's technology cannot improve. Yet, wind tunnels and aerodynamics absorbed most of the NACA's energy and funds, limiting development of other fields. Moreover, the growing industry worked its way into the Committee and asked for more and more research.

There is no trace of industry's funds spent on NACA and it is possible to wonder if there was any. In fact, the industry with the help of the military induced certain studies and benefited from the results. The services expected results, which they got, but they also expected to be ahead of all other countries in the field. In two instances NACA failed to take the lead, jet propulsion and missiles. The next chapter, dealing with jet propulsion, will investigate and illustrate the difficulties of the agency, and will try to determine how the services lost confidence in the ability of the Committee to fulfill its role. The best way to show where problems developed is to give a survey of the state of jet propulsion in America before World War II and present the work of NACA on the subject. But the major problem linked to jet propulsion is that Britain and Germany developed jet engines before America. This put the U.S. military services in a position of inferiority. The Army solved the problem partially through cooperation with the British, but this cooperation was to have a negative impact on NACA even though the Committee created a Subcommittee on Jet Propulsion.

3.0 JET PROPULSION

3.1 THE CONCEPT OF JET PROPULSION

The jet was revolutionary because it required a total rethinking of propulsion methods. The jet, like the propeller, works by thrusting large quantities of air backwards and the plane forward, in consequence of Isaac Newton's third law. But while the regular engine/propeller combination will generate the energy necessary to propel the aircraft by "thrusting a large weight of air backwards...in the form of a large air slipstream...," the air coming out of the jet engine will be a jet of gas at very high speed and very high temperature.[1] For the lay reader the simplest illustration of this law is a balloon. If one blows air in a balloon and holds the end, the pressure inside the balloon will be equal everywhere, but when one releases the end of the balloon, it will begin an erratic

[1] Rolls Royce, *The Jet Engine* (Derby, England: BPCC Ltd., 1986), 2.

flight until it falls on the floor. In this brief flight, the air under pressure escapes through the hole and propels the balloon in the opposite direction. This balloon uses jet propulsion.

There are several types of jet engines, the gas turbine engine (very common today), the ram jet, the pulse jet, the rocket, the turbo/ram jet, and the turbo rocket, differing only in the way in which each supplies and converts the energy into power for flight. At the end of the 1910s engineers understood the concept of the gas turbine, in Europe and the United States they proposed to use it for aircraft, but development stalled. In the 1930s the closest engine to the gas turbine was the turbosupercharger, a gas turbine with the combustion chamber replaced by a reciprocating engine. The compressor of the turbo delivers air to the engine, and the exhaust of the engine supplies the hot gases to drive the turbine. Both NACA and the other agencies worked with these projects at different paces and with different goals. It produced speeds far superior to the conventional engine (from 250 mph to 500 mph and above). Jets were much lighter that piston engines and this compensated for a relatively lower efficiency.

The British reached that step first, with the Whittle engine, while America, and particularly NACA, rejected the idea. The English owed much to the work of Frank Whittle. He considered jet propulsion in the mid 1920s but did not receive an official contract for jet propulsion work until June 1939. However, by mid-decade he had created a small company and advanced the development of his engine in spite of funding problems. Although the R.A.F.'s school provided, at first, the necessary structure to begin research, Whittle did not go into the full development of his project until the strategy of the Air Ministry included jets as a top priority.

The British delivered a jet engine and aircraft to the United States but we must compare, as the U.S. military services must have done, the way the British developed a viable engine. NACA and the British both possessed the technology necessary to develop jets. Funding problems crippled Whittle's company, yet he continued working on his engine. NACA did not suffer from the same financial pressure, nonetheless it did not undertake more than preliminary studies of jet propulsion.

3.2 EARLY WORK ON JET PROPULSION IN THE UNITED STATES

Between 1923 and 1933 NACA published four reports on or related to jet propulsion, all recommending against the development of jet engines. In 1923 NACA published a report by Edgar Buckingham, who had studied jet propulsion for airplanes at the request of the Engineering Division of the Army Air Service. NACA's Subcommittee on Power Plants for Aircraft published Buckingham's work as a technical report. It examined jet propulsion with regard to fuel consumption and weight of machinery and concluded that the difference between fuel use of air-screw propulsion and jet propulsion was too unfavorable. At the highest speeds "jet propulsion by the proposed method requir[ed] about 5 times as much fuel as ordinary screw propulsion."[2] The report ended by saying that "at best, the combined engine-compressor unit could be at least 50 per cent heavier than an ordinary aviation engine of the same power, and probably considerably more."[3] Experiments showed that even at the highest flying speeds of the time (250 mph), this type of propulsion would require at least four times more fuel than the ordinary air screw. In addition, Buckingham said engineers should expect all kinds of problems, with the fuel injection system, the great number of piston, valves, and moving parts, and "the chances of breakdown and the difficulties of upkeep would be correspondingly increased."[4] He concluded that "there does not appear to be, at present, any prospect whatever that jet propulsion of the sort here considered will ever be of practical value, even for military purposes...[ ] Propulsion by the reaction of a simple jet can not compete, in any respect, with air screw propulsion at such flying speeds as are now in prospect."[5] In the next two decades NACA seemed to accept that view as its official policy because the agency's studies used the same argument to dismiss jets. The Advisory Committee did not even create the committee on jet propulsion until 1941.[6]

---

2 Edgar Buckingham, Technical Report No. 159. "Jet Propulsion for Airplanes", *National Advisory Committee for Aeronautics Annual Report 1923* (Washington, D.C.: Government Printing Office, 1924), 83.

3 Buckingham, 84.

4 Buckingham, 83.

5 Buckingham, 85.

6 Marsden Ware, Technical Report No.230, "Description and Laboratory Tests of a Roots Type Aircraft Engine Supercharger," *National Advisory Committee for Aeronautics Annual Report 1925* (Washington, D.C.: Government Printing Office, 1926), 461. One step to the development of jet propulsion was the supercharger which NACA studied in 1925. The Committee designed a Roots type supercharger, and the test showed that the "Roots type blower [was] well adapted for use as an aircraft engine supercharger."

In 1932 NACA published another report on jet propulsion. Eastman N. Jacobs and James M. Shoemaker of the Langley Memorial Aeronautical Laboratory did a series of tests to determine how much "a jet could be increased by the use of thrust augmentors...," using a compressed air jet and a series of annular guides surrounding the jet to act as thrust augmentors.[7] The study asserted that jet propulsion for airplanes would not be feasible unless they could add thrust augmentors and aimed to determine how much these would increase the thrust. Although tests indicated that they could increase thrust, the report closed by saying: "it is not likely that the large increase mentioned in reference 1 [i.e. Buckingham's study] as necessary to the successful application of jet propulsion to aircraft can be obtained."[8]

By the mid-thirties engineers began to think about developing a gas turbine, but there were difficulties, the main one being fabricating turbine buckets that could resist the high-temperatures of the exhaust gases. Wright Field engineers did not undertake any research on jet engines until materials could withstand temperatures of 2,500 F. By mid-decade scientists solved that problem by creating new alloys. Engineers at Wright Field and General Electric began to look into the gas turbine on a theoretical level, but they never mentioned the probable weight of an airplane flying with a jet engine. They assumed that it would be useless to develop a gas turbine unless that engine would consume much less fuel that the conventional engine. The search for competitiveness on this

---

[7] Eastman N. Jacobs and James M. Shoemaker, "Test on Thrust Augmentors for Jet Propulsion," Technical Note No.231, *U. S. National Advisory Committee for Aeronautics: Technical Notes* (Washington, D.C.: Government Printing Office, 1932), 1.

[8] Jacobs and Shoemaker, 5.

basis "led to the calculation of such extremely high values for the required components efficiencies and blade temperatures that successful development seemed to be utterly hopeless."[9]

In the 1930s R. E. Lasley, a former steam-turbine engineer for Allis-Chalmer, obtained several patents for gas turbines between 1925 and 1930, making the only recorded attempt at developing the gas turbine engine. He created the Lasley Turbine Motor Company in Waukigan, Illinois, and by 1934 he could show movies of his engine running. Still it was extremely inefficient.[10] Financial difficulties pushed him to try to "sell" his project to the Navy and the Army. Army representatives visited his company in August 1934, but reported that the efficiency of the engine was too low. They consulted with General Electric, which did not recommend any development until turbine blades could withstand temperatures of 2,500 F. Lasley's program quickly withered for lack of funding. He could not bring the efficiency of the new engine to compete with the reciprocating engine. Lasley, like most engineers, looked for a jet engine that could compete with the traditional engine on the basis of fuel consumption, range and efficiency ratios at lower speeds. He never considered the possibility of a less efficient but much lighter engine.

Lasley's problem were common among researchers studying gas turbines in the 1930s. Scientists conceived jet propulsion as best suited for driving a propeller rather than a propulsion system. Furthermore, they considered power

---

9 Robert Schlaifer, *Development of Aircraft Engines* (Boston: Graduate School of Business Administration Harvard University, 1950), 442.

10 Lasley could not claim an operation efficiency superior to 11.6%.

plants for aircraft as fixed, both in its design and speed. This belief held until 1939 when General Electric conducted a new analysis of gas turbines that led to the conclusion that "a turbojet would be superior to a turboprop as a way of utilizing the gas turbine."[11] Consequently, it would not be before the end of the 1930s that engineers and physicists would regard jet propulsion as feasible. The next step would be how best to develop jet propulsion. NACA's strategy did not include jet propulsion, and the executives never began research in the field. Worse, von Karman incident shows that NACA was not open to new information.

In 1935 Theodore von Karman attended a conference in Italy where reports on high speed flight in Italy and Germany, (and work on the turbine in Switzerland) amazed him. Returning to the United States, he tried to alert the government on the state of research in those countries. He felt that both the U.S. military services and civilian agencies, including NACA, did not consider any need to advance high-speed flight research and/or development. He proposed to Dr. George Lewis, director of NACA's Research Laboratory, that a large wind tunnel be built to augment the small high-speed wind tunnels of the Advisory Committee. This new type of tunnel would generate wind up to 650 miles per hour. Karman told Lewis that such a tunnel would be the only way to keep pace with the rest of the world. Lewis turned down the idea because "he did not see why anybody would need a major wind tunnel that developed a speed greater

[11] *Aircraft Engines*, 445.

that the speed of the propeller blade tips -about 500 to 600 miles per hour, the point of maximum propeller efficiency."[12]

Two years later Karman again urged the U.S. government to undertake serious research of jet propulsion, but the government turned him down. In 1938 a high-level board of engineers that had studied gas turbines reported that gas turbines would work perfectly with ships but were far too bulky and heavy for an aircraft. Research on the gas turbine remained at a standstill until General Arnold called Karman for a meeting in Washington in 1939. Even then it was too late and the U.S. military had to rely on British technology to breach the gap created by jet propulsion. Karman's warning had no effect, but it did alert Arnold to the fact that NACA might be causing a U.S. technical lag.

3.3 THE BRITISH ACHIEVEMENT

NACA had the technical knowledge to develop jet engines. The Committee was in charge of basic research in the United States, had large budgets, and its laboratories were equipped with some of the best wind tunnels in the world. But the agency did not undertake the needed long-term basic research and long-term experimentation on jet propulsion. Since the U.S. military services acquired a British engine it is important to investigate the English development, and

[12] Theodore von Karman, *The Wind and Beyond: Pioneer in Aviation and Pathfinder in Space* (Boston: Little, Brown and Company, 1967), 224.

particularly whether it was part of the R.A.F.'s overall technical strategy. It is also essential to consider the structure that surrounded the development of the Whittle engine.

Frank Whittle began his work in aircraft as an aircraft apprentice in the Royal Air Force. In 1926 he became a Flight Cadet at the Royal Air Force College, Cranwell, England where he wrote a thesis on "Future Developments in Aircraft Design," and discovered that "to be possible to fly fast and far it would be necessary to fly at very great heights -far higher than was possible with the then conventional piston engine and propeller."[13] The traditional piston and supercharged piston engines lost power above 20,000 feet. Therefore, Whittle began to investigate the possibilities for another power plant that could function at high speed and at very high altitude. He did not come up with the idea of the turbojet until the end of 1929 because he did not realize the potential of a combination of rocket propulsion and gas turbines driving propellers. His basic idea was to increase "the compressor compression ratio and substitute a turbine for the piston engine."[14] The Central Flying School provided the resources necessary (funds and laboratory) to begin the study of jet propulsion, and as the project evolved Whittle's superiors referred him to the Army Ministry. When Whittle discussed his project with Dr. A. A. Griffith, the specialist of propulsion at the British Army Ministry's laboratory, the latter seriously challenged the idea. He gave two reasons: an error in the calculations and concern that the "gas

[13] Frank Whittle, "The Birth of the Jet Engine in Britain," *The Jet Age: Forty Years of Jet Aviation*, ed. Walter J. Boyne and Donald S. Lopez (Washington, D.C.: Smithsonian Institution Press, 1979), 3.

[14] Whittle, 4.

turbine was impracticable in the light of the long history of failure and lack of materials capable of withstanding the high combination of temperature and stress in turbine blading."[15] The Air Ministry denied further study under its authority.

In January 1930 Whittle applied for a Patent on his jet engine, which he received late in 1931. Throughout 1931 he tried unsuccessfully to involve private companies in his project, by mid-1932 his only success was the publication of his study on jet propulsion. Although one of NACA's successes had been the collection of information throughout the world, the Committee never showed any interest in the project. In 1932 Whittle tried again to attract interest of the Air Ministry but with little result. After he completed a two year course in engineering the Air Ministry sent him to Cambridge University on the basis of his outstanding achievement.[16] He graduated in June 1936 and both his tutor and a professor of aerodynamics encouraged him to pursue his study of jet propulsion.

Finances remained a problem, but L.L. Whyte, a physicist turned banker, provided the capital necessary to create a small company, and in March 1936 Whittle established Power Jets Ltd. Although the Air Ministry did not see any breakthrough in Whittle's work, it bought shares in his company and requested that Whittle spend no more than six hours per week working on jet propulsion.[17]

As early as April 12, 1937, the company subjected its engine to test runs. Ignition problems, a valve spring in the fuel injector, and the vaporizer caused uncontrollable accelerations but financial problems even more pressing than

---

[15] Whittle, 4.

[16] The Air Ministry had discontinued that program but decided to permit an exception.

[17] In that project the 2,000-pound-plane would fly at very high altitude and at a speed approaching 500 mph.

technical ones and caused the team to stop research in July. In that dismal period Power Jet Ltd. received help from a different source. Sir Henry Tizard, Chairman of the Aeronautical Research Council, encouraged and favored Whittle's plans and the British Thomson-Houston Company (B.T.H.) accepted shares in the company as payment for work and parts. Finally, the Air Ministry agreed to finance the project. Its interest in Whittle's work put a seal of secrecy on the whole project and Whittle could no longer seek private funding.

At the end of June 1939, D. R. Pye, Director of Scientific Research (DSR), approved Whittle's engine and offered a contract for a flight engine--the W1--and an experimental aircraft--the E28/39.[18] Though the financial situation improved combustion problems persisted. Still at the end of 1940, the team had almost completed the W.1. and was working on the W.1X, a slightly modified version. The Gloster Company neared completion on the E28/39 in early 1941 and on April 6 test pilot P.E.G. Sayer accomplished the first taxiing run. By mid 1941 the team cleared the aircraft for flight.

Whittle also worked on the W-2-B, a variant of the W2 series, but German bombings on or near the research site caused serious delays.[19] According to Whittle, the British feared that the German attacks on Landywood Works would alter the production of the jewel of the R.A.F., the W-2-B. Consequently, the British and U.S. authorities, namely Sir Henry Tizard for Great Britain, and General Henry H. Arnold for the U.S. Army Air Forces, decided to transfer the

[18] The DSR was part of the British Air Ministry.

[19] The W-2-B was a 1,600 lb static version of the W.1. Engineers developed the W-2-B to fly on a twin-engined jet fighter plane.

W-2-B in the United States and begin production. On October 1, 1941, the British sent a disassembled W.1X and a team consisting one senior engineer and two technicians from Power Jets Ltd. to America and sent General Electric a set of drawings of the W-2-B (which became the I-14 in the United States). One year later General Electric was ready to test the I-14, and Bell Aircraft completed the XP-59A, a fighter that would use two I-14s.

3.4 THE U.S. GETS A JET-ENGINE

Major General Henry H. Arnold, Chief of the U.S. Army Air Forces, played a key role in the acquisition of the British jet engine. Early in 1941 he became interested in jet propulsion. He mentioned in his memoirs *Global Mission* that he realized the progress of research and development in the field of jet engines during his trip to England, and wrote: "One of the most important pieces of information I was able to secure [there] concerned the first jet-propelled airplane the British had built--a plane [ ] I had never seen before."[20] The new plane and its Whittle engine impressed him all the more as he knew that "no such device had yet advanced beyond the drawing-board stage..." in America.[21] When he saw the plane taxi around the airfield and make short flights, he talked with Sir Henry Tizard, with Colonel Moore-Brabizon, Minister of Aircraft Production,

---

20 Henry H. Arnold, *Global Mission* (New York: Harper & Brothers, Publishers, 1949), 242.

21 Arnold, 242.

and with Lord Beaverbrook, director of British Aircraft Production. They "unanimously" agreed to give him all plans and specifications of the engine.[22] Although Arnold would keep the Committee out of the development of the jet engine in the United States, early in 1941 he wrote to the Chairman of NACA urging the creation of a committee to study jet propulsion.

3.5 CREATION OF A SUBCOMMITTEE ON JET PROPULSION

Early in 1941 two elements combined and led to the creation of the Subcommittee on Jet Propulsion. On February 11, 1941, the Committee on Power Plants for Aircraft recommended the creation of a Special Subcommittee on Auxiliary Jet Propulsion, to correlate studies by agencies within and outside the government.[23] On February 25, General Arnold, a member of NACA, wrote to Vannevar Bush, Chairman of NACA, to request that the Committee investigate the methods of jet propulsion. Urging NACA to undertake studies of jet propulsion, Arnold stressed two points, the importance of the subject and the need for immediate steps to evaluate it. On February 27 the Executive Committee approved the creation of the special committee.

---

[22] Arnold, 242.

[23] Committee on Power Plants for Aircraft, NACA, Washington, D.C., to Executive Committee of NACA, Washington, D.C., 11 February, 1941, TLS, "Records Relation to NACA Committee and Subcommittee" 117.15, Record Group 255, National Archives Record Center, Suitland, Maryland.

On March 10, Bush wrote Dr. Jerome Hunsaker to ask for suggestions as to the constitution of this group. He emphasized the pressure exercised by General Arnold and Rear Admiral John H. Towers and concluded by saying "It seems to me that on this matter we should move with the utmost promptitude."[24] Bush's words seem to indicate that he was desperately trying to make up for lost time. On that same day Bush wrote Arnold to inform him of his decision to create a committee to study jet propulsion, but said it would require expensive and large scale experimentation, and "funds for this purpose to the extent needed will undoubtedly not be available under present appropriations."[25]

Bush offered the chairmanship of the Committee to the eighty-three year old W. F. Durand, who accepted on March 18. The same day Bush sent detailed information on the new committee. On March 29 Bush organized NACA's Special Committee on Jet Propulsion.[26] However, the Executive Committee did not intend the new subcommittee to concentrate on jet propulsion, but rather expected the subcommittee to have a range of investigation from assisted take-off to main propulsion apparatus. He also advised Durand to "evaluate the entire situation and construct plans," and favored "a careful review before one could

---

[24] Vannevar Bush, Washington, D.C., to Dr. Jerome C. Hunsaker, Cambridge, Massachusetts, 10 March 1941. TLS. "Records Relation to NACA Committee and Subcommittee," 117.15, Record Group 255, National Archives Record Center, Suitland, Maryland.

[25] Vannevar Bush, [Washington, D.C.], to General Arnold, Washington, D.C., TLS, 10 March 1941, "Records Relation to NACA Committee and Subcommittee," 117.15, Record Group 255, National Archives Record Center, Suitland, Maryland, 1.

[26] Membership of the Special Committee: Dr. W. F. Durand, Chairman; Prof. C. Richard Soderberg, M.I.T., Vice Chairman; R. C. Allen, Allis Chalmers Company; Dr. L. W. Chubb, Westinghouse Electric and Manufacturing Company; Prof. A. G. Christie, Johns Hopkins University;Dr. Hugh L. Dryden, National Bureau of Standards; A. R. Stevenson, General Electric Company; General O. P. Echols, Army Air Corps; Captain S. M. Kraus, United States Navy; plus three ex officio members: Dr. J. C. Hunsaker; Dr. G. W. Lewis; Dr. G. J. Mead.

initiate expensive experimentation."[27] Once again NACA's did not take jet propulsion seriously, and did not provide for continuing investigation.

The committee studied the jet engines developed by three private companies and recommended that General Electric develop a gas turbine engine for propeller drive, Westinghouse Electric a straight turbojet engine, and Allis-Chalmers an engine using a combined discharge of hot gas and compressed air. The contract that the special committee recommended for General Electric was totally independent of the work that General Electric undertook for the Army Air Forces.

Despite its work on turbosuperchargers, the Committee did not have anything to do with the Whittle engine. In a letter to George W. Gray, written after the war, Jerome C. Hunsaker said that "[n]either NACA nor Durand had anything to do with initiating that type [the Whittle engine]."[28] The military, and particularly General Arnold, held back information on the Whittle engine. A certain bitterness appeared in Hunsaker's words as he described the late role of NACA in jet propulsion:

> The Durand Committee had nothing to do directly with the I-16 development or with the succeeding British type G. E. jobs like the I-40, but as the extreme secrecy surrounding these jobs was released they were kept informed of these developments as a basis for guidance in considering other projects.[29]

---

[27] Vannevar Bush, [New York], to W. F. Durand, California, 18 March 1941, TLS, "Records Relation to NACA Committee and Subcommittee," 117.15, Record Group 255, National Archives Record Center, Suitland, Maryland, 1.

[28] Jerome C. Hunsaker, [Washington, D.C.], to George W. Gray, New York, 4 September 1946, TLS, General Records (Decimal file) 623-623-1, Record Group 255, National Archives Record Center, Suitland, Maryland.

[29] Ibid

Arnold did not explain why NACA did not participate in the development of the Whittle engine and in *Global Mission*, devoted hardly a page to the question. But he played a key role in the obtaining a jet engine from Great Britain and there was more behind the acquisition of the Whittle engine than just getting the engine.

3.6 TRANSFERRING THE WHITTLE ENGINE

On July 21, 1941, following Arnold's request, the Ministry of Air Production in London allowed the British Air Commission to release information on the Whittle engine. The U.S. Army Air Forces in Washington then sent Major D. J. Keirn to England primarily to collect information on the Whittle engine. By that time the military services had referred the problem of jet propulsion to the Durand Committee, and its work interested the War Department Air Corps Materiel and Division in Washington.

By mid August the Army Air Forces decided to survey the installations needed to produce the Whittle engine in the United States, and set up a special committee consisting of Colonel A. J. Lyon, Major C. Brandt and Mr. D. R. Shoultz from General Electric. Arnold particularly requested the appointment of D. R. Schoultz. In its report the committee stated that there was nothing "obscure or unusual in the manufacturing methods required."[30] The industrial

[30] A. J. Lyon, London, England, to General Arnold, Washington, D.C., 16 August 1941, TLS, "Engine,

infrastructure available in America could easily support production, and eventually, improve the engines if Great Britain released specifications. In that light, the committee made five recommendations regarding the Whittle engine. It wanted the immediate production of a small number of W-2-B engines; the modification of the turbine design to facilitate quantity production. It advised to secure a W.1X unit from the Ministry of Air Production, and to make the Whittle engine the basis of a major development project. Finally, the committee favored inviting Wing Commander Whittle "to the United States for consultations."[31]

At the end of August, Keirn visited Whittle's Power Jets Ltd. company at Lutterworth, England, where he met Whittle, who accompanied him on his four-day tour of the facilities. He saw the Lutterworth plant, where English engineers did experimental work, constructed, modified, and tested the Whittle engine. The Ministry of Air Production had assigned production of the engine to the Rover company and anticipated the delivery of the first thirty engines in early spring of 1942. After that date it expected a production rate of twenty engines per week. In the report Keirn included a description of the power plant and combustion chambers. He observed testing of the W.1X and W2MK1V, and the work of engineers to reduce the weight of the W-2-B. But the essential conclusion of this description was the comparison between the jet engine and the conventional power plants. Engineers and manufacturers admitted that the

VDT, Vol. II to Whittle," Box 48, Entry 22, Record Group 18, National Archives, Main Building, Washington, D.C., 1.

[31] A. J. Lyon, to General Arnold, 16 August 1941, 1.

advantage of the jet propulsion engine was its light weight. Jets would fly faster and higher and the light engine would compensate for extra fuel consumption.

Keirn indicated that such an engine required a specially designed aircraft, but concluded that the W-2-B offered the perfect solution to the "power-plant problem of the very high speed interceptor type airplane."[32] The Whittle engine was most efficient at high speed for short periods, about two hours. Production cost also represented an undeniable advantage being a small fraction of the cost of the traditional engine and propeller. Furthermore, the installation of the engine was extremely simple and the cooling and oil systems that plagued the conventional engines were more reliable in the jet.[33] Finally, the jet engine greatly reduced the landing gear weight. Keirn saw three drawbacks; the great speed could make taxiing dangerous for other aircraft and personnel; operation could be difficult on soft soils; and the engine still suffered from compressor surging problems (but he added that by early spring of 1942 the engine should operate satisfactorily).

Hence, on September 4th and 5th General Arnold held conferences in his office "regarding the feasibility and desirability of going into immediate production in this country on the Whittle engine project...."[34] For the first meeting he invited Air Corps staff members General Spatz, General Echols, Lt.

---

[32] Major D. J. Keirn, "Report on Visit to Power Jets, Lutterworth, England 28-31 August 1941," "Engine, VDT, Vol. II to Whittle," Box 48, Entry 22, Record Group 18, National Archives, Main Building, Washington, D.C., 6.

[33] A large part of NACA's success relied on improving the cooling of radial engines and cowling. The new engine would affect NACA in the area where it was best at.

[34] "Notes on Conferences" from Notebook prepared in Major Chidlaw's Office, 9 September 1941, 1.

Colonel Gardner, Majors Chidlaw, Brandt and Irvine, and four people from the General Electric Company, A.R. Stevenson, Jr., Engineering Staff Assistant; S. R. Puffer, Design Engineer on Turbo Installations; R. C. Muir, Vice President in Charge of Engineering; and D. R. Schoults, Industrial Research Department. After examining preliminary data with the General Electric representatives, the members of the committee determined that the company could duplicate engines provided that "the production drawings [were] made available to them from England in the immediate future."[35] General Electric engineers expected to produce the first engine within six months and two additional engines two months later. General Arnold insisted that the project remain "*absolutely* secret."[36] After agreeing on the different details of the operation, the members formulated a cable and immediately dispatched it to Lt. Col. Moore-Brabizon at the Ministry of Air Production in London. It said the committee had decided to produce the Whittle engine in the United States and requested the loan of one engine, an airplane, and engineering personnel to start the program. The urgency of the war incited the services to ask for the loan of Frank Whittle himself, as well as any key personnel that British production could spare.

During that meeting the committee decided to invite Lawrence Bell from Bell Aircraft Company to Washington the following morning to a meeting on the development of the aircraft. Hence, on September 5, Bell and his Chief Engineer, H. M. Poyer, met General Echols for a preliminary meeting. Echols proposed

---

[35] "Notes on Conferences," 1.

[36] "Notes on Conferences," 2.

that Bell participate in the entire development of the aircraft; however, he insisted on the utmost secrecy on the part of his company. Bell agreed, and they arranged for a conference at 2:30 that afternoon in Generäl Arnold's office.[37] After Arnold reviewed the decisions taken during the conference the previous day they discussed the aircraft. The members decided to build fifteen engines, designated as Type I Supercharger Development, and three airplanes, called XP-59A. The two companies would work in very close collaboration, but they had to take *"such steps as may be necessary to enjoin secrecy throughout."*[38] The Materiel Division took charge of preparing the contracts. To preserve secrecy, it forwarded all data relative to the project, production drawings, or materiel specifications, to the General Electric Company which then duplicated and forwarded the necessary information to the Bell Company.

This project certainly required confidentiality, but to cast such a shroud of secrecy on the Whittle engine reflected Arnold's and the military establishment's distrust of NACA. Arnold had resolved to set up barriers between the military and NACA. During the meeting on September 5, he declared that in order to maintain secrecy on the Whittle engine "he would take the necessary steps to see that this project was withdrawn from the program of the Durand (NACA) Jet Propulsion Committee."[39] This decision seems rather drastic. NACA had worked

---

[37] The following persons attended the afternoon conference: General Spatz, General Echols, General Kenny, Lt. Colonel Carroll, Lt. Colonel Gardner, Majors Chidlaw, Irvine and Brandt; D. R. Schoults from General Electric, plus Bell and Poyer of the Bell Aircraft Company.

[38] "Notes on Conferences," 3.

[39] "Notes on Conferences", 3.

so closely with the military, and on secret projects for many years, and the services had already referred the project to the Committee.

On September 11, General Royce cabled that Great Britain would send the Whittle engine and drawings by ship, and send a mechanic and an engineer. They could not spare a single-engine test airplane but promised to send, the following May, the prototype of a twin-engine fighter with a production engine. Nine days after Royce's cable, Lyon, writing from the Office of Special Army Observer in London, described with enthusiasm the jet engines he had seen. "I am greatly impressed with the amount of both basic and applied research that had been done on Jet Propulsion and Gas Turbines in England."[40] He regretted the "time lost in this field..." and asked the headquarters to consider the creation of a new power plant laboratory, a Jet Propulsion and Gas Turbine laboratory, at Wright Field.[41] Thus, the United States should imitate the work of the British and consider the Whittle engine only as a stop gap measure. Lyon also suggested that the military initiate large programs in cooperation with the industry. He stressed that the success of the English engine relied on basic research but never mentioned NACA, which possessed the best equipment for testing developments in aeronautics and had as its main task basic research.

On September 22, A. H. Self of the British Air Commission in Washington informed the Secretary of War H. L. Stimson that the British authorities had approved the release of all requested information on the Whittle engine, but

---

[40] A. J. Lyon, London, England, to General Arnold, Washington, D.C., 20 September 1941, TLS, "Engine, VDT, Vol. II to Whittle," Box 48, Entry 22, Record Group 18, National Archives, Main Building, Washington, D.C.

[41] A. J. Lyon to General Arnold 20 September 1941.

stressed that the British insisted on secrecy. Britain sent a Whittle W.1X and two men from Power Jets Ltd., D. M. Walker, Chief Test Engineer, and G. B. Bozzoni, Experimental Fitter. The engine and the technicians reached the United States at the beginning of October and development began immediately at General Electric and Bell Aircraft Companies. As work progressed the engineers felt that in order to exploit the fullest possibilities of the engine-airplane they needed to tunnel test the XP-59A (the American version of the E28/39) and the Type I Supercharger. Echols wrote Arnold to discuss the problem and requested authority "to confer with Dr. George W. Lewis, Director of Aeronautical Research, N.A.C.A., regarding an accelerated test program on this project."[42] A note in the margin of the text dated November 14 1941 stated that General Arnold "did not wish to tunnel test at NACA in view of the 'secrecy' of project."[43] The note also bore the laconic sentence, "Decision is NO!"[44] Engineers would have to work without tunnel tests. Development of the engines continued at the companies and a year after the British had delivered the first Whittle engine, the Bell XP-59A started its test flight program at Muroc Lake.[45] But NACA was no longer the initiator and coordinator of research and innovation. It had failed where the British had succeeded. The military considered that Whittle had no financial support for his research but he had managed to

---

[42] Oliver P. Echols, Washington, D.C., to General Arnold, [Washington, D.C.], "Memorandum for General Arnold," 13 November 1941, TDS, "Engine, VDT, Vol. II to Whittle," Box 48, Entry 22, Record Group 18, National Archives, Main Building, Washington, D.C.

[43] "Memorandum" 13 November 1941.

[44] Ibid.

[45] Today Edwards Air Force Base.

accomplish the necessary breakthrough. In addition the U.S. military had to acknowledge that the English project had remained strictly military. Whittle was a cadet at Cranwell and wrote his thesis during his studies at the military college. Though he created Power Jets Ltd. with the help of a banker, the turning point of the development of his engine was the interest of the Royal Air Force in his work. The main reason for this change was that manufacturers' strategy included research and development, and they modified the structure of their companies, by adding research laboratories to their facilities, to achieve their goal.

All this undoubtedly brought to the surface what Alex Roland called a "crisis of confidence."[46] Roland did not investigate the reasons for that turning point but he suggested that the "crisis of jet propulsion" made the services realize that from that time on they could only rely on themselves to develop new technologies. Jet propulsion demonstrated that NACA was no longer necessary, that industry could undertake secret projects and carry them out and also assume a large part of basic research. Manufacturers had harmonized their strategy--maintain large military contracts--and the structure of their companies--adding large and efficient research laboratories--to achieve their goals.

Another motive for the military's attitude was the unbalance of the equilibrium on which the relationship NACA-military services rested. Until World War II NACA set its agenda. It usually studied problems with a very scientific outlook, aiming at fundamental research before developing new

---

[46] *Model Research*, 192.

technology. This meant a certain loss of time because some studies led nowhere and loss of funds. The results always accrued to the military, and they had no reason to complain, but with World War II military efficiency set the agenda. The military wanted an aircraft that could fly fast and at high altitude. NACA's theoretical research on jet engines was far behind Great Britain's and during the war the industry offered greater certainty because firms had been working on turbosuperchargers for a few years. Moreover, industrialists could deal with secrecy, even though they were not tied to the military the way NACA was, and their chief goal was to keep the customer happy.

Furthermore, in 1939 General Arnold had met Theodore von Karman to discuss jet propulsion, and Arnold indicated "his strong belief that the U.S. Army Corps could not reach the top in aviation and remain there without doing experimental work to advance the art."[47] He wanted to know the kind of facilities required to make "a major advance in flight."[48] Karman advised him to build the "right" kind of wind tunnel, one that could produce winds at least four hundred miles per hour. He also added that the U.S. program in that field was lagging because the United States lacked knowledge in that area, hence, singling out NACA as the cause of the trouble! Arnold authorized a contract for the construction of a 20-foot, 40,000 horse-power wind tunnel at Wright Field. At this point Karman presented a very important piece of evidence as to the alteration of the relationship between NACA and the services:

---

[47] Karman, 225.

[48] Karman, 226.

This decision conflicted with the point of view of NACA, and a battle broke out over the future of aeronautical research. NACA Director George Lewis declared flatly that it was NACA's duty to develop research facilities such as wind tunnels for the Armed Services. Lewis, in fact, opposed military sponsorship of research altogether. He even told me that my job as a teacher at Cal Tech had only one purpose -to educate good research men for NACA. I couldn't have disagreed more.

Ironically, in one meeting between Lewis and Arnold, Lewis also happened to say that if a twenty-foot wind tunnel had to be built NACA should build it, and he, Lewis could get the only man who could design a good one."[49]

That man was Karman, and he already cooperated with Arnold! Karman added that this event started the Air Corps' own research program, and developed a close working relationship between himself and Arnold and, consequently, the Air Force.

Jet propulsion brought to the surface the discrepancies among basic research, the need to keep up with international competition, and the priorities of national defense, and it hurt NACA's reputation with the military even though the Committee had an impressive record in aerodynamics. Congress had created NACA to advise the United States on aviation policy. Very early the Committee supported the aircraft industry. The industry developed in the late 1920s and 1930s and became a powerful alternative to NACA. After rising to power the industry discredited the Advisory Committee by accusing the Committee of lagging in basic research on jet engines in the prewar period. The next chapter will discuss the ambiguities of the situation, and particularly the difficulties of NACA in the light of the rise of an alternative power, the protest of that power against the agency, and finally NACA's problems in the perspective of Chandler's model.

---

[49] Karman, 226.

4.0 NACA AND JET PROPULSION

4.1 THE RISE OF THE INDUSTRY

It is not possible to pinpoint any single cause for NACA's failure to develop jet propulsion before the British or the Germans, but two things were particularly important, the rise of the aircraft industry and the way in which NACA defined its mission. This chapter examines industry's role in shaping jet propulsion. A large part of that role was due to its change of attitude toward NACA. Industry pushed its way into the Committee, and its influence grew with its size. After World II, NACA created an Industry Consulting Committee that allowed industrialists to make more suggestions as to the problems that NACA had to attack. Yet industry also competed with the Committee, since more and more engineers chose to work for industry's higher salaries. Once industry went from research and small production to the one of mass production, it had less need of

NACA. Between the flight of the Wright brothers and World War II the aviation industry came of age, and this was critical in shaping NACA and military's stand on development of jets in World War II.

NACA was born with the beginnings of aeronautics, and it took the lead in aeronautical research in America by coordinating the work of industry and the military and setting standards for production, instrumentation, and safety. At the end of World War I the NACA board realized the potential of civilian aeronautics for business and civilian transport, as well as for all sectors of industry, and encouraged the government to support industry. Year after year, the Committee continued to investigate what it saw as the problems of flight--aerodynamics, aircraft structure, aircraft materials, lightning hazards and meteorology--and increasingly focused on specific questions. Thus, its investigations moved from work on a general understanding of the process of flight and study of the atmosphere to detailed analysis of parts of now-conventional plane; it studied spark plugs, fuels and the materials (glues, wood or plastics) needed to built aircraft. This shift from the general to the particular and toward maximizing the potentials inherent in existing technologies set barriers that would become difficult, and even impossible, to overcome. Moreover, the Executive Committee chose which problems to investigate, not allowing subcommittees to decide whether one problem looked more promising than another.

In 1918 the Committee had recommended that the United States take the lead in the "development of aviation for commercial as well as military purposes," and that it work on fundamental research.[1] This commitment tied NACA to a limited area of research because each field required permanent investment and research in long-term planning, and NACA did not have the funds necessary to study every problem in the same manner. Also, the Advisory Committee and the Executive Committee took charge of long-term planning they never created committees or subcommittees to forecast developments in aeronautics.

In a sense, NACA was a victim of its own success. It solved many aerodynamic problems and some of its solutions produced Collier trophies.[2] These validated Committee's work and encouraged its members to push forward in familiar areas of research--those areas maximizing the potential of existing technological forms--making NACA a service agency for both the government and industry--consistently working to maximize efficiency in existing technologies rather than working toward the development of new forms of technology. Meantime, industry created research laboratories and invested large amounts of money in that field.[3]

NACA, in a sense, created its own competition. Before World War I, there was no "aviation industry." World War I and the combat use of aircraft in Europe piqued the interest of both industry and the military and, falling in line

---

1 NACA, *National Advisory Committee for Aeronautics Fourth Annual Report, 1918* (Washington, D.C.: U.S. Government Printing Office, 1919), 51.

2 The Collier trophy was the most prestigious American award in aeronautics. It rewarded annually the greatest achievement in aviation. But the value of the invention had to be demonstrated in use the year preceding the award.

3 See (1) Alan I. Marcus and Howard P. Segal., *Technology in America: A Brief History* (San Diego, California: Harcourt Brace Javanovich Publishers, 1989), 300. (2) Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: The Belknap Press of Harvard University Press, 1977), 374. (3) Carroll W. Pursell, Jr., *Technology in America: A History of Individuals and Ideas* (Cambridge, Mass.: The M.I.T. Press, rpt. 1986), 5.

behind NACA, the U.S. government came to see aviation an important means of defense. The Advisory Committee gained the support of the military services because of the European experience between 1914 and 1918. Foregoing the easy path of stressing just military applications, NACA argued that a strong private aeronautic industry could easily turn to war-time production.

In the late 1920s and the early 1930s, NACA's forecast about the future of aviation was realized. The public showed a high degree of interest in the new means of transport once industry and NACA improved safety, reliability, and comfort of flight. The Air Mail Service, in operation since 1916-17, proved the feasibility of airplanes for business. The prospect of investing in the aviation industry appealed increasingly to industrialists and entrepreneurs. During the 1930s industry developed, but also split. Two industries appeared, one civilian, another military. Though many companies built both commercial and military aircraft the bulk of profits came from military contracts.

The take-off of the aircraft industry dates from the 1930s, when the government awarded its first large contracts to aircraft manufacturers. From 1931 to 1937 the percentage of large manufacturers' business through government contracts increased dramatically: government contracts represented 59% of the total sales for Boeing, 79% of Consolidated, 91% of Douglas Aircraft, and 100% of Martin.[4] These contracts helped the companies build factories, improve production methods and productivity, train workers, and establish sound production systems. The military market had begun to dominate aeronautics.

---

[4] Holley, 22.

The military aircraft market yielded much, but it demanded much as well. The military wanted aircraft that flew higher, faster, and farther, requirements that pushed industry to invest in continued research and development and integrate backward into research areas.[5] Before industry started putting so much emphasis on research and development, manufacturers produced and marketed aircraft using standards designs. Companies started integrating research as part of a company's business when research and development became essential to survival, and that moment arrived with the military contracting. Civilian aviation had required initial investments in research and development, but once a viable aircraft appeared on the market industry could carry on research at minimal levels, often on an *ad hoc* basis. Military aviation however implied full-scale, ongoing research and development.

Such a demand burdened those firms that took on the military's new contracts. NACA, pre-eminent in research, could well have gotten "an unending" list of investigations to conduct for the military and industry. Instead, the prospect of large military contracts and the increase of profit that went with it encouraged half a dozen manufacturers to conduct very aggressive research and development programs. To encourage an aggressive research policy the Army invested in industry, between 1926 and 1938, some 60% of its research funds.[6] The aviation industry incorporated research and experiment branches and "the

---

5 Chandler declared that backward integration "resulted from a desire to have an assured stock of supplies at a reasonable price on hand and available whenever the manufacturing plants need them." Chandler, 291. In the case considered here, research was the "stock of supplies," and the manufacturers realized they needed Research and Development divisions just to compete. Furthermore, industry could rely permanently on NACA to accomplish all the research it needed.

6 Holley, 24.

practice among virtually all manufacturers seeking Army contracts for experimental air materiel was to bid as low as possible, even accepting a loss, on experimental work in the hope of recouping later with high volume production contracts."[7] Companies could offer low-cost experimental work and still make profits when the military placed large production contracts. NACA could not because it could not get any return from large contracts. This form of dumping certainly harmed NACA, which could not compete. It had to request additional funds if the military asked it for research and experimental work. This took time, and Congress might refuse. The manufacturers concentrated only on experimental work that "promis[ed] some more or less immediate return in a subsequent production contract to amortize costs."[8] Their unwillingness to "indulge in extensive fundamental research" probably left NACA with the less glorious part of research, the part that the military, a few years later, would appraise as ineffective research program. Hence, research contracted to the Committee was very narrow in focus or very expensive. Precise studies requested by the military combined with the Committee's strategy of maximizing result, oriented research in a direction that would prove harmful for the agency. The Army's investment in industry incited manufacturers to undertake more fundamental and experimental research. Such a policy greatly harmed NACA. In the 1930s, competition forced industry to seek the best engineers by offering better wages. NACA's budgets precluded competition for labor; employee

---

[7] Holley, 24-25.

[8] Holley, 25.

turnover at NACA began to rise; and the Committee struggled to hold engineering talent. This constituted an important change. For talented engineers, NACA had been the premier place to spend a career. When industry surged ahead in research, employment patterns shifted.

NACA helped create the aeronautic industry, but the relationship between patron and client developed into a complex association. After the enactment of the Air Commerce Act of 1926, the Advisory Committee distanced itself from the industry, and sought to pursue its primary interest, fundamental research. But the Committee could not concentrate on pure research without alienating its main support or the military services. Pure research would lead NACA to perfect specialized areas, for instance aerodynamics, but to lose sight of the overall thrust in aeronautical research. The members of the Advisory Committee confused immediate successes--aerodynamics, cowling and cooling--with the future in aerodynamics. The Committee ignored that new types of power plants that would increase the speed of aircraft and did not extend its research to any such as jets.

The relation between industry, the military and NACA furnished the basis for the Committee's successes, but also its fall. The forum for this interaction was the Senate Committee on Armed Services hearings held at the end of April 1953.[9] During those hearings senators questioned NACA's relation to military services. Dr. Hugh L. Dryden, then Chairman of NACA, set out to explain how the three parties discussed the problems of aeronautics. The military, industry,

[9] After World War II NACA had to appear in front of Senate Committee on Armed Services to defend its appropriations, and to justify its new construction program.

and NACA sat on committees and subcommittees that met twice or three times a year. During these meetings, members coordinated the research effort, but in a surprising fashion. If industry or the military had any difficulty, they would submit it and discuss the problem during the meeting. But Dryden admitted that the meetings produced "no great written report," the "work [was] done by conversation," and finally the "whole business [was] handled rather informally."[10] NACA's Industry Consulting Committee did no better and industry criticized the Committee's policy of keeping industry representatives off the Executive Committee that decided the studies to undertake.

Later in the hearing Senator Symington inquired about Dryden's comments that NACA did development work for private companies and that the "work was paid for in the cost of the airplane."[11] In fact NACA could not do development work for the companies, but could go "if it is a military project, to the military officer, if he agrees and considers in the light of other priorities that this should be gone into by NACA, then it goes through the Military Department, as a request to the NACA."[12] The cost of that development, however, would then come out of NACA's appropriations, and the Committee would not get any form of reimbursement.

Such a procedure allowed industry to arrange for NACA, or rather the government, to pay for basic research, which explains why the industry wanted

---

[10] Congress, Senate, Committee on Armed Services, *National Advisory Committee for Aeronautics Construction Program: Hearing before the Committee on Armed Services*, 83rd. Cong., 1st sess., April 30 1953, S.1805. Washington, D.C.: Government Printing Office, 1953, 12.

[11] Committee on Armed Services, 20.

[12] Committee on Armed Services, 20.

more representatives on the Advisory Committee. Industry obtained such representation with the enactment of Public Law 549 on May 25 1948, increasing the membership of the Advisory Committee to seventeen members. But as early as 1945, the Executive Committee had created an Industry Consulting Committee, which met for the first time on September 26, 1945. The Committee gave private companies access to NACA, but they wanted even more. They wanted to sit on the Advisory Committee and Executive Committee. The Advisory Committee had always opposed the entry of industry representatives on that committee. That was, Dr. J. Hunsaker admitted, "a conscious policy... of not having industry representatives..." on NACA.[13] When Senator Mitchell said that industry had only seventy-one representatives on NACA committees and subcommittees, Hunsaker replied: "I suppose the manufacturing part of industry would never be content unless they ran the committee."[14] The rise of industry had created tension between the big companies and their former patron. After the enactment of the Air Commerce Act, NACA expected the aircraft industry to be independent of the Committee. However, manufacturers wanted to have more influence on the research program of the agency. The Committee resisted this "invasion" by industry, but kept cooperating with the manufacturers because they were the ones who ultimately applied NACA's results into

---

[13] Congress, Senate, Special Committee Investigating the National Defense Program, *Investigation of the National Defense Program: Hearings before a Special Committee Investigating the National Defense Program*, 79th Cong., 2nd sess., 27 February 1946. Washington, D.C.: Government Printing Office, 1946, 16912.

[14] Special Committee Investigating the National Defense Program, 16812.

production. Furthermore, the military listened and worked more and more with industry.

This cooperation did not result in the development of jet propulsion. Industry, and particularly General Electric, started work on turbosuperchargers but not on jet engines. But the cooperation between NACA, the industry and the services became a very convenient argument to explain the late development of the jet engine. The shift to jet propulsion depended on fundamental research and even more on the decision of agency executives to study the question. Furthermore, it required the development and construction of a new type of wind tunnel, and wind tunnels furnished the cornerstone of NACA's research. Yet, NACA refused to build the new wind tunnel in the mid-thirties when Theodore von Karman suggested such a development and refused to contemplate jet propulsion as the power plant of the future. Industry could then blame NACA for failing to accomplish its task. It became the perfect scapegoat.

Industry's resentment of NACA's relationship to the military services also loomed large. The military had adopted the pattern of taking airplanes away from the manufacturers, and giving them to the Committee for testing even before they came off the production line. NACA would check industry's work and decide what changes were necessary. Jet propulsion was a good case with which to tarnish the image of the Committee, raise doubts about its efficiency in the minds of the military, and shift from industry to NACA the accusation of lagging behind the Germans and the British. All these elements combined, and finally resulted in an open criticism, or at least severe questioning, of NACA.

4.2 *CRITICISM OF NACA*

4.2.1 LETTERS FROM THREE COMPANIES

The criticism that emerged in 1953 had been raised before. In 1945 the Special Committee of the U.S. Senate (which became known as the Mead Committee) sent questionnaires to the aviation industry, asking about the services that NACA had rendered.[15] The responses of three manufacturers--Bell Aircraft Corporation, Douglas Aircraft and Consolidated Vultee--are particularly revealing.[16] Roy Schoults from Bell Aircraft praised the work done in cooperation with NACA before September 1939 but noticed that wartime basic research took low priority.[17] He declared that "[p]rewar *basic research* done by NACA was of inestimable value to Bell Aircraft in carrying out the design work on airplanes

---

[15] Questionnaire: (Q1) Has your company requested the National Advisory Committee for Aeronautics to work on specific research problems? (Q2) If the answer to No. 1 is "yes", specify the problems and the steps that were taken by the National Advisory Committee for Aeronautics, to your knowledge, in compliance with your request, furnishing copies of correspondence or other data which, in your opinion, are material to a determination of the manner in which and the speed with which the research on such problems was conducted. (Q3) The Committee desires your appraisal of the scope of investigation and research conducted by the National Advisory Committee for Aeronautics, specifying in detail the research projects engaged in and appraising their usefulness to the future of aeronautics. (Q4) Comment upon the administrative structure and personnel of the National Advisory Committee for Aeronautics and the general of its activities in aircraft research and development, specifying in detail the advantages or shortcomings of the National Advisory Committee for Aeronautics as they have come to your attention, offering any suggestions you may care to, either as to the modification of the administrative structure or staff or operations of the National Advisory Committee for Aeronautics, or any suggestions you may care to make as to other government-sponsored research and development activities, which, in your opinion, should contribute to the most desirable development of aircraft in the future for the United States.

[16] The three letters discussed here were found at NASA's History Office, in a file cabinet containing documents assembled by Alex Roland. It was not possible to locate those letters at the National Archives where NACA's documents have been deposited. The letters have been included in Appendix B.

[17] After September 8 1939 the President of the United States declared a limited emergency, and the Aeronautical Mobilization Plan governed the activities of NACA.

built *during the war.*"[18] They were generally satisfied with the work of NACA but Consolidated Vultee voiced discontentment, as Albert E. Lombard, Jr. criticized both NACA's structure and the way the committees ran test programs for companies, claiming cooperation with NACA "ha[d] not been entirely satisfactory..." to the company.[19] Douglas stressed the good cooperation between the company and NACA but added that the agency's committees should include more members whose background, experience, and training had been connected with the design of aircraft, aircraft engines, and operation of engine.

All shared two complaints. They wanted industry representation on the Advisory Committee and a larger voice on standing committees and subcommittees. In addition, each had particular grievances. Douglas Aircraft thought the committees were too large to be efficient and insisted that NACA's inability to compete with private industries' wages led to a high turnover and a lack of quality personnel, which it identified as the root of the problem. Douglas Aircraft's A. E. Raymond pointed at the same weaknesses that Alfred Chandler identified as the cause of corporate difficulties. Successful companies had struggled to change their overall strategies, their structure, and their personnel. Raymond argued that NACA had also to change. He advised the appointment of competent committee members, openness to new ideas coming from industry, and a revision of the Committee's strategy. Bell Aircraft regretted the lack of

[18] Roy Schoults, Vice-President Engineering, Bell Aircraft Corporation to Special Committee Investigating the National Defense Program, to the attention of James A. Mead, TLS, January 14 1946, filing cabinet put together by Alex Roland, NASA History Office Reporters Building, Washington, D.C., 3.

[19] Albert E. Lombard, Jr., Engineering Consultant Consolidated Vultee Aircraft Corporation to James Mead, TLS, 16 January 1946, filing cabinet on NACA put together by Alex Roland, NASA History Office Reporters Building, Washington, D.C..

more capable technical people on the committees and wanted committee members to become "*actively engaged* in the post-war period in the technical work within the cognizance of each of the committees or subcommittees."[20]

The sharpest criticism came from Consolidated Vultee, which judged NACA's basic research program "inadequate." NACA had neglected basic research during the war; the Committee's research program had not been sufficiently broad and systematic, and "[t]here ha[d] been a tendency to jump around and hit the high spots."[21] Finally, it challenged NACA's basic research program in high speed flight, charging that the agency had lacked sufficient vision in planning and accusing the Committee of withholding data necessary to industry. Lombard and Raymond identified NACA's difficulties in the same terms that Chandler uses to describe large corporations: the lack of advanced planning, a neglect of basic research essential to the aviation industry, and an inhibiting structure. Such letters expressed industry hostility toward NACA; the Mead Committee hearings yielded even sharper criticisms.

4.2.2 HEARINGS

After the end of the war in Europe, a Special Committee of the Senate, (which became known as the Mead Committee) began investigating the national

---

[20] Schoults to Mead Committee, 3.

[21] Lombard to Mead Committee 16 January 1946, 1.

defense program.[22] In August 1945, the Mead committee held hearings with the West coast air-frame industry and in the fall in Boston with East coast manufacturers. During hearings on the West coast industry spokesmen made some statements in regard to the general research and development program of the air-frame industry and called for a strengthened research and development program in the post war era. This prompted the Mead committee to hold another hearing with the agency in charge of the U.S. research program, NACA. On February 27, 1946, Jerome C. Hunsaker, Chairman of NACA, testified in front of the Senate committee.

Senator Mitchell introduced the hearing: "It was suggested critically by some of the people that NACA was not doing the basic research program which was thought necessary during the war and in development for the war."[23] Hunsaker, expressed surprise at the comments and undertook to defend and explain the work of NACA. The questions focused immediately on the relation between NACA and industry when Senator Ferguson asked whether NACA took suggestions from industry. It appeared that the Advisory Committee sought suggestions, counsel and advice from industry. But the hearing revealed a peculiar organization; the Executive Committee was not smaller than the Advisory Committee. The quantity of work that the agency faced required a larger administrative staff, and, in the early 1930s, the only solution to this problem had been to increase the number of members sitting on the Executive

---

22 From its chairman James A. Mead.

23 Special Committee Investigating the National Defense Program, 16807.

Committee. This change marked the Committee's recognition that the agency required a larger administration or a body of full-time administrators. NACA, however, never created the new administration. Instead it had kept the committee-managed organization, where the same members sat on the both the Advisory Committee and the Executive Committee and chaired committees and subcommittees. In spite of this change, Senator Ferguson questioned the efficiency of a committee that met so rarely.

When the investigation turned to the industry's influence on NACA, the committee challenged the poor representation of industry on committees and subcommittees, only seventy-one representatives out of more than 300. As Senator Mitchell stressed that poor representation, Hunsaker declared that industry would rule the agency if it could, but conceded that it had been conscious policy to exclude industry representatives from the Advisory Committee.

Senator Ferguson pressed inquiries about the initiation of new projects in the agency. Hunsaker revealed that a field employee or engineer who wished to undertake a new project had to make a case to the subcommittee under which he worked, which could kill it. Even if the engineer convinced the subcommittee of the validity of his views, the Executive Committee still had to approve it and allocate funds. In addition, the standing committees and subcommittees had no financial independence, and Hunsaker even said "We don't give them any responsibility, certainly no budgetary responsibility."[24] The Advisory Committee decided the future of all new ideas.

As the hearing continued, Senator Mitchell pointed out that industry representatives should have been on the Advisory Committee ten years earlier, their industry's influence might have motivated NACA to undertake basic research in more promising areas. He referred to the planning of long-term policy and indicated that the aircraft manufacturers would have helped NACA in directing the programs of research. At that point Mitchell introduced the notion of basic research, and got Hunsaker to assert that basic research was THE work of NACA. The senator shifted the conversation to jet propulsion and tried to prove that NACA did not have enough men working on jet engines. The Germans had some 27,000 people working on jet propulsion. Although Hunsaker tried to dismiss that figure by declaring that the Germans' work was "development of gadgets and searching for miracles," Mitchell answered that "they found some very nice miracles which we didn't find in jet propulsion, for instance...."[25] Hunsaker emphasized that Germany was ahead because it had started research in 1933. Mitchell seized the occasion to prove, and to have Hunsaker admit, that the Germans kept doing research until at least 1940. Hunsaker's defensive statement conveyed the idea that basic research had been the key to the development of jets. Mitchell argued that NACA should have begun research on jet propulsion in the early 1930s.

---

[24] Special Committee Investigating the National Defense Program, 16814.

[25] Special Committee Investigating the National Defense Program, 16817.

Though NACA did not know about secret German developments, Mitchell blamed the agency since it was in charge of collecting information abroad. Hunsaker countered that NACA was not a spy agency.[26] Senator Mead insisted on determining the responsibilities for the lack of basic research in order to prevent the same situation from happening again. Pressing Hunsaker for a clear answer, he said:

> Now, if each agency having something to do in this particular matter insulated itself within its own prescribed powers, then this great country of ours, with all of its power and resources, may run into another situation that we ran into just before this war began, and even though we made a tremendous spurt after the emergency was upon us, and we were forced to do so to protect our very lives, it does redound to the credit of organizations that are to sense and prepare and plan these things in a period of safety and security when war emergency is not upon us."[27]

Senator Mitchell urged Hunsaker: "Would you admit, to begin with, Doctor, that insofar as aviation is concerned, as compared with Germany, we were ill prepared?"[28] Though Hunsaker tried to evade the questions, he acknowledged that Germany possessed a superior fighter at the beginning of the war, and that the first flight of a German jet fighter took place in 1938. He also admitted that the U.S., hence NACA, had not done any work on jet propulsion in the 1930s and very little during the war. Mitchell's question centered on responsibility, and he quoted a representative of the air-frame industry:

> Again, in the field of jet propulsion, in spite of our recognized leadership in exhaust engine turbine design and practice, this country had found itself following instead of leading. Apparently, NACA did not recognize the promise of a gas turbine jet propulsion power plant, and followed instead the less promising path taken by the Italians in the use of the conventional engines rather than jet propulsion. NACA has belatedly recognized the significance of the turbo jet and has now adapted its facilities at Cleveland for the testing of such devices."[29]

---

[26] Though no members of the senate committee brought up the charges, NACA did not take advantage of Whittle publication in 1932.

[27] Special Committee Investigating the National Defense Program,16819.

[28] Special Committee Investigating the National Defense Program, 16819.

[29] Special Committee Investigating the National Defense Program, 16820.

This statement clearly accused NACA of failing to study the right field at the right time. Ignorant of the military's experiences with the Whittle engine, Hunsaker argued that everybody had failed to see the problem--the military, NACA, and people like Vannevar Bush and General Arnold. Senator Mead's question reintroduced the issue of responsibility. Hunsaker had mentioned that NACA had the knowledge necessary to develop jet propulsion in the early 1930s. Mead asked "you said a while ago that you had the knowledge and the science; well, what do you do with it? I am wondering who is responsible, who turned it down? Why didn't we have it?"[30] Mead cornered Hunsaker who admitted that NACA's preference was a conscious decision, and that the Committee, and to a larger extent the whole government, preferred to work on the quality of the 50,000 airplanes that America produced each year rather than a new engine. During the war America had gotten a Whittle engine and did not have to concentrate on jet engine research. Moreover, the war in Europe and the Pacific had demanded more and more airplanes. Mass production was the top priority for the nation. In that exchange Hunsaker used "we" instead of the word "NACA" or the "United States" and this prompted the following questions:

> Senator Mitchell. When you say "we," you don't mean NACA?
> Doctor Hunsaker. "...when I say "we," I mean NACA."
> Senator Mitchell. Then it was your decision which led to taking it on or not taking it on?
> Doctor Hunsaker. We made the decision.[31]

Thus, the Mead hearings legitimized industry's complaints against NACA, singled out the agency as the principle cause for the lag in developing jet engines.

---

[30] Special Committee Investigating the National Defense Program, 16821.

[31] Special Committee Investigating the National Defense Program, 16821.

Hunsaker had difficulty answering some questions and was unconvincing in his defense of NACA. What emerged was that NACA did not want to pursue jet propulsion. Through these hearings, industry, Congress and the military gained an official statement of responsibility. The military preferred to work directly with manufacturers. The aircraft industry wanted alternative power plants that were more efficient and matched military requirements. The hearings suggested that the organization of the Committee caused difficulties that undermined its relationship to the military, challenging both the strategy and the structure of the National Advisory Committee for Aeronautics.

4.3 CHANDLER'S MODEL: A COMPLEMENTARY EXPLANATION

Although Alfred D. Chandler focuses explicitly on the development of large-scale business organization, the principles he employs serve to analyze any large-scale, productive organization. Large-scale organizations, he found, require coordination among multiple autonomous divisions, or units. This division into units was a response to information flow and to growth that could slow down innovation. NACA failed to develop an analog of the coordination among functionally autonomous units, which big business achieved, though it faced the same problems of coordination and information flow. Quite the reverse NACA organization moved increasingly toward specialized units administered by a single, all powerful central committee. This form of organization slowed and at times prevented the flow of information and ideas in the agency, especially from the bottom up.

Administration, an essential activity in any large-scale organization, differs from the actual "business" (buying, producing, or selling), and in a large enterprise is, or should be, the work of executives concerned more with allocation and coordination than production. Their tasks usually include long-range planning, allocation and coordination of resources, and the evaluation of the work of subunits. As a company grows, the executives in charge of administration need to build a decentralized structure in which departments maintain some degree of autonomy. Most importantly, effective administrations seldom deal with day to day business; they concentrate on administration. In a decentralized structure, the head of each department has the authority to allocate resources, move personnel, funds, and equipment, and is fully responsible for the performance of that unit. Another essential task of the department head is long-term policy planning. He must be aware of the changing needs of customers--and the necessity to expand into new areas.

NACA did not market goods, but did offer basic research, which the military and industry integrated into new aircraft or into improving existing ones. The Advisory Committee, but mainly the Executive Committee, dealt with the administrative tasks, allocating the funds and deciding on the creation or dismissal of committees and subcommittees. The Executive Committee was everywhere. It administered NACA, creating committees and subcommittees, and checking and controlling committee work through the control exercised by the chairman of each committee and subcommittee--himself a member of the Advisory Committee. Everything came from above: finances, new projects, and all other decisions essential the initiation or survival of a project. Individual engineers had few opportunities to affect the direction of basic research.

Industry representatives stressed that NACA did not develop jets before other nation because it did not undertake the research necessary to develop a reliable jet engine. The crucial period for the agency was the early 1930s because the development of a new engine required at least ten years--just as it does today. Thus, if the military expected a viable jet engine by 1941, research should have begun in the first half of the 1930s. During that period NACA enjoyed widespread recognition for its achievement on cowling and cooling. It excelled those areas and kept working in them. Because the Advisory Committee and the Executive Committee never felt the necessity to create a committee in charge of studying jet propulsion, because the early studies did not make the jet engine a promising development, and because the agency considered that the speed of aircraft was set and could not improve even with a different power plant it continued to concentrate on cowlings and the maximization of aerodynamics. A committee structure as tight as the one NACA had produced could enhance the Committee's decision to concentrate on a particular area of research because the limited number of members reduced disagreement. It also inhibited flow of information and discussion of the new technology.

The way in which members of the Advisory Committee chose the members of the Executive Committee played a critical role. The method of appointment limited who could sit on NACA's most important committee and influenced and impeded the flow of information and ideas. The members of the Advisory Committee certainly played the most important role in shaping the direction of research. The criteria on which members of the Advisory Committee elected the Executive Committee affected the work of that committee. The members of the Executive Committee had to live in or near Washington, D.C., and give "[their] time wholly or chiefly" to the work of the Committee.[32] If members served on the Executive Committee on the basis of residence--over and above their technical and administrative qualifications--one can question the ability of such a committee to direct the aeronautical program of the nation. The Advisory Committee admitted that it needed more executives but was not willing to maintain a body of full-time administrators.

The law creating NACA specified that the members of the Advisory Committee would serve without pay. This raises questions about their ability to focus on important problems, when they met only a few times in a year and had no economic or professional stake in NACA's success. The work of a member consisted in advising and orienting the nation's aeronautical research. In one year, members attended the two meetings of the Advisory Committee, and those who sat on the Executive Committee attended the monthly meetings. If they sat on committees and/or subcommittees they also attended these meetings. As the

[32] See *Rules and Regulations*, Article III, p.3.

workload of the Executive Committee increased, the Advisory committee decided that it would be beneficial if a larger number of members sat on the Executive Committee and thus helped with the different tasks. The number of officials fluctuated, and very often the meetings of the Executive Committee assembled the whole Advisory Committee.[33] In 1946, during the hearings held by the Mead Committee, the senators seemed puzzled by the fact that the Executive Committee was not a smaller group than the Main Committee.

Apparently, the entire Advisory Committee sat on the Executive Committee.[34] This "swollen" Executive Committee raises several questions. How could members afford to leave their jobs every month to serve on a committee without compensation? What were the policies of their full-time employers? Whatever the policy of their companies, however, it affected the efficiency of the Committee. NACA, through its officials, always insisted on its independence, and defended itself against close ties with a particular group of interest. In any case, and on the basis of evidence available, it offers two interpretations for the student of NACA.

First, the members served without compensation from their companies. Thus, a task that required dedication offered little reward. They simply could not spend all their energy, or at least the energy necessary, to keep the Committee ahead of other nations in aeronautics. On the other hand, if the companies or services financed their representatives (and this seems more plausible) the

---

33 This de-facto increase in membership never appeared officially in the Rules or in the Regulations.

34 The *Annual Report* listed the members of both the Advisory and the Executive Committees, by 1933 the listing of the Executive Committee disappeared. Moreover in 1932 all but two members of the Advisory Committee sat on the Executive Committee, and one might infer that this practice began in the early 1930s.

members could act as "lobbyists," favoring particular research programs or studies that would benefit their organization. In both cases, the appointees could not work for the good of NACA. The agency needed a full-time staff that could handle administrative tasks and scientific matters, but it never got one.

World War II forced the aviation industry into mass production, which required rationalizing methods of production, and its efficiency contrasted with NACA's static organization and program. The military and Congress began doubting NACA effectiveness and at the end of the war the Committee came under close scrutiny. The hearings of 1946 pointed at the weaknesses of NACA and senators questioned the role of NACA's main committee. According to Weberian theory, committees are conservative by definition and seek preservation of their status. In the early 1930s NACA tried to retain the favor of Congress through public relations. In fact, the Chairman of the Main Committee, Joseph S. Ames, was very concerned with a policy of public service. He strove to gain the confidence of both industry and the Federal Government. In 1935 the Smithsonian Institution awarded Ames the Langley Gold medal for his leadership of NACA. In a twenty-year period the Committee had been very successful in devising cowlings for radial air-cooled engines and a low-drag wing, finding the best location of engines or other equipment, and studying of the drag of landing gears. Hence, the agency had no reason to change. At the level of strategy this would have meant abandoning an area of great immediate success to embark on a program that could have serious drawbacks. Preliminary studies did not encourage further development, and studying jet propulsion, would require new laboratories and new and expensive equipment. It might be difficult to expect that an agency very successful in a particular branch of research would suddenly shift to an unpromising field.

Further, its success physically and financially "locked" it in. In the late 1920s NACA's cowling was a success, the Committee applied its usual "recipe" to this success. Between 1915 and 1958 the Committee built over fifty wind tunnels. These tunnels had different applications. They could not, however, solve all problems. Still, the tunnel dictated the areas of research NACA should go into. The Committee's approach further limited it. When it worked on a problem like drag, cooling, de-icing or lightning hazard it pursued technical perfection. This meant investment of considerable time and energy in a single problem. Such strategy virtually precluded the study of other more preliminary questions. Aerodynamics research undoubtedly conformed to this pattern. NACA worked to reduce drag through the use of wind tunnels. In addition to this "rule of the wind tunnel" NACA had a sense of mission, which appeared through its reports.

After the enactment of the Air Commerce Act of 1926 the Committee always worked to present the aviation industry as a successful enterprise. NACA praised industry's achievement as a private industry and compared it to competitors in Europe where governments openly financed aviation. On the other hand, the Committee stressed the vital role that aviation played for the military. NACA's public relations strategy portrayed the agency as falling between those two components and as the necessary link between them two. But

NACA did not change its relationship to industry even though industry changed. The members of the Advisory Committee convinced themselves that the only way to carry out this mission was through in-depth technical research, the accumulation of data on all phenomena related to flight.

The creation of subcommittees in the fields of aerodynamics and power plants express the Committee's priority in the 1930s aerodynamics. In 1916 NACA created the Committee on Power Plants for Aircraft (called Motive Power in 1916), and in 1919 the Committee on Aerodynamics. Both remained standing committees throughout NACA's existence. The Executive Committee regularly created subcommittees reporting to either the Aerodynamics or the Power Plants committee. Between 1926 and 1939 the Executive Committee established a single subcommittee under the Committee on Power Plants, (the Subcommittee on Aircraft Fuels in 1935), and during the same period seven subcommittees and special subcommittees under the Committee on Aerodynamics. Between 1940 and 1945 it established nine subcommittees for Power Plants and only five for Aerodynamics. In the thirties, when NACA was relatively "free" to undertake research, it studied airship, vibration and flutter, and seaplanes. In the early forties the war in Europe and the military, under the impetus of General H. H. Arnold, guided the development of research on power plants with the establishment of the Subcommittee on Turbines or the Subcommittee on Compressors and Turbines in 1940, and finally the Subcommittee on Jet Propulsion in 1941. The effort of the early 1940s came too late, and was the result of outside pressure. In the 1930s NACA had not created these committees because it had not identified the jet engine as the next generation of engines. Instead it continued to work on old successes.

NACA failed to achieve a structure appropriate to its situation. From 1915 to 1958 it kept the same organization, simply increasing the membership of the Advisory Committee from twelve to fifteen members, and later to seventeen. The organizational chart did not undergo major changes in forty-four years. Industry grew and aerodynamics was no longer the frontier of research but NACA pushed on. The structure that allowed collection of information, and lobbying and pushing for industry throttled information from bottom. In 1958, the Advisory Committee reorganized NACA around spaceflight research. This unexpected reorganization followed the events of late 1957, Sputnik 1 and 2. The outcry that followed the launching of the first earth satellites coerced NACA to revise its strategy thus change its structure. This reorganization had little meaning because the Committee disappeared that same year.

A decentralized structure would have implied the creation of responsible departments, the head of which would have been accountable for the performance of his department. He could give orders, move and use personnel, funds and equipments. The heads of committees and subcommittees never had such authority. The Advisory Committee never allowed them any administrative responsibility. The chairmen of committees and subcommittees mainly had to make sure that members carried out properly the recommendation of the Executive Committee.

5.0 CONCLUSION

Congress created the National Advisory Committee for Aeronautics in 1915 to advise the nation on its aeronautical program. NACA saw its task as the collection and distribution of information to researchers, building a strong private industry, the coordination between military and the industry, and doing fundamental research. The agency succeeded in its work on aerodynamics and in encouraging the industry, but it failed to change its strategy to meet the new era of big industry and it did not see new problems and possibilities. Jets and jet propulsion showed this difficulty because the Army Air Forces went to industry to solve the question jet engines.

Change began in the 1920s, the Federal Government enacted the Air Commerce Act in 1926, liberating the Committee from all routine tasks, and allowing NACA to concentrate on the fundamental research that it considered its basic duty. Between 1915 and 1926 the Committee had supported the aviation industry by requesting that the government help the infant industry built a strong productive core. By the mid 1930s the government gave large contracts to industry. During the same period the Committee was very successful with the development of the NACA cowling device. This success pushed the Committee to maximize its research in the field of aerodynamics and consequently to neglect areas such as jet propulsion. Although industry wanted a larger representation on the Advisory Committee, NACA resisted and insisted on cooperative ventures with manufacturers only under military contracts. Ironically, the industry that the Committee supported so strongly, criticized the agency openly in the mid 1940s.

Early in 1941 the Army Air Forces in the person of General Arnold realized that the English R.A.F. had accomplished a tremendous breakthrough with the development of the first jet fighter. When the Army surveyed the English installation they realized that the British accomplishment resulted from long fundamental research. In February 1941 General Arnold had required NACA to create a special committee on jet propulsion, but it proved useless to the military. Arnold deliberately kept the Whittle engine secret from NACA although engineers working on the engine needed tunnel tests at NACA. There was no reason Arnold should have taken that decision since NACA possessed some of the best wind tunnels in the world, had worked on many secret projects for the services before, and had the reputation of respecting the secrecy of private companies' projects. The only plausible explanation is that the military did not consider NACA a reliable and efficient agency. Industry appeared more efficient.

The change of attitude has both internal and external reasons, but they all relate to administrative matters.

A useful approach to understand this process is through Chandler's model of strategy and structure. His model described businesses but the analysis and the principles he used can also serve to study any large-scale, productive organization. A new situation, large-scale business, required the creation of a new structure functionally autonomous units run by a separate administration. Situation changed but NACA did not. Quite the contrary, it continued to rely on a single, all powerful central authority, the Executive Committee, which had been appropriate but which inhibited the study of new projects such as jet propulsion. Furthermore, as competition forced manufacturers to integrate basic research in their structure, they embarked on aggressive research and development programs, beyond NACA's ability to compete.

It is not possible to isolate one reason for the termination of NACA, at the heart of the change that left NACA behind was development of industry and services' unwillingness to accept some of NACA's weaknesses. Thus, they worked increasingly with industry. Ironically, industry quickly criticized NACA and added fuel to the belief that the agency was inadequate for military needs. All these factors combined and led to the termination of NACA in 1958.

SELECTED BIBLIOGRAPHY

5.1 PRIMARY SOURCES: PUBLISHED DOCUMENTS

U.S. Congress. Senate. Committee on Armed Services. *National Advisory Committee for Aeronautics Construction Program: Hearing before the Committee on Armed Services.* S.1805, 83rd Cong., 1st. Sess., 30 April 1953. Washington, D.C.: U.S. Government Printing Office, 1953.

U.S. Congress. Senate. Subcommittee of the Committee on Armed Services. *National Advisory Committee for Aeronautics Construction Program.* H.R. 7328, 83rd Cong., 2nd Sess., 4 May 1954. Washington, D.C.: U.S. Government Printing Office, 1954.

U.S. Congress. Senate. Subcommittee of the Committee on Armed Services. *National Advisory Committee for Aeronautics Construction Program: Hearing before the Subcommittee of the Committee on Armed Services.* H.R. 2581 (H.R. 3761), 84th Cong., 1st Sess., 15 March 1955. Washington, D.C.: U.S. Government Printing Office, 1955.

U.S. Congress. Senate. Committee on Armed Services. *Visit to the Facilities of the National Advisory Committee for Aeronautics.* Report prepared by Senator Ralph E. Flanders. 84th Cong., 1st Sess., April 8 to April 14 1955.

U.S. Congress. Senate. Special Committee Investigating the National Defense Program. *Investigation of the National Defense Program: Hearing before a Speciall Committee Investigating the National Defense Program.* S.Res. 55, Part 33, 79th Cong., 1st Sess., 27 February 1946. Washington, D.C.: U.S. Government Printing Office, 1946.

National Advisory Committee for Aeronautics. *Annual Report of the National Advisory Committee for Aeronautics 1915-1958*. Washington, D.C.: U.S. Government Printing Office, 1915-1958.

5.2 PRIMARY SOURCES: UNPUBLISHED DOCUMENTS AND LETTERS

5.2.1 NATIONAL ARCHIVES, MAIN BUILDING, WASHINGTON, D.C.:

5.2.1.1 RECORD GROUP 18 ENTRY 22 BOX 48

Arnold, Henry H., War Department, Washington, D.C., to Major Donald J. Keirn, Wright Field, Dayton, Ohio, 15 October 1941. TLS.

--------., Washington, D. C., to Lt. Col. J. T. C. Moore-Brabizon, Minister of Aircraft Production, London, England, [4 September 1941]. TD.

--------., to Lt. Col. J. T. C. Moore-Brabizon, Minister of Aircraft Production, London, England, 30 September 1941. TLS.

--------., to Col. Alfred J. Lyon, American Embassy, London, England, 2 October 1941. TLS.

--------., to General Echols, 6 November 1941. TDS.

--------., to General Echols, 27 November 1941. TDS.

--------., "Memorandum for the Under Secretary of War," Army Air Forces, Washington, D.C., to Under Secretary of War, Washington, D.C., 27 October 1943. TDS.

Carroll, F. O., Lt. Col. Chief Experimental Engineering Section, Air Corps, to General O. P. Echols, Washington, D.C., 25 November 1941. TDS.

--------., Chief Experimental Engineering Section, Air Corps, to Assistant Chief of Staff, Army Air Forces Materiel Command, Washington, D.C., 11 July 1942. TDS.

Chidlaw, B. W., to General Echols, [4 September 1941]. Memo, TD.

--------., Chief Materiel Division, to Materiel Command Wright Field, Dayton, Ohio, 22 June 1943. TLS.

"Contract" TD. Contract between the War Department and General Electric. Approved 23 December 1941.

Echols, Oliver P., Chief Materiel Divison, to General Henry H. Arnold, Memorandum, 13 November 1941. TDS.

--------., "Memorandum for Chief of Army Air Forces," to Chief of Army Air Forces, 26 February 1942. TLS.

Higgs, J. H., to Major Beebe, 5 August 1941. TDS.

Hill, Roderic, British Air Commission, Washington, D.C., to General Henry H. Arnold, War Department, Washington, D.C., 29 September 1941. TLS.

Hunsaker, Jerome C., Chairman National Advisory Committee for Aeronautics, Washington, D.C., to General Henry H. Arnold, War Department, Washington, D.C., 13 October 1941. TLS. Attached was a digest with a comparison of General Electric, Allis Chalmers and Westinghouse proposals for a jet engine.

Keirn, D. J., London, England. "Report on visit to Power Jets, Lutterworth, England, August 28-31, 1941." TDS.

--------., Wright Field, Materiel Division, War Department, "Progress report -Turbo Supercharger Type I," to Chief, Materiel Division, Washington, D.C., 31 October 1941. TDS.

--------., Major, to General Henry H. Arnold, 3 November 1941. TLS.

--------., to Chief, Materiel Division, Washington, D.C., 1 January 1942. TLS.

Kepner, W. E., San Francisco, Calif., to General Henry H. Arnold, War Department, Washington, D.C., 3 June 1943. TLS.

[Lee] M/A London, England, to MILID War Department, Washington, D.C., 4 July 1941. TDS.

Lyon, A. J. Col., London, England, to Major General Henrly H. Arnold, 16 August 1941. TDS.

--------., American Embassy, London, England, to General Henry H. Arnold, 20 September 1941. TLS.

Miller, J. C., General Electric Company, Schenectady, N.Y., to General G. F. Kenney, Materiel Division, War Department, Wright Field, Dayton, Ohio, 20 February 1940. TLS.

--------., General Electric Company, Schenectady, N.Y., to Assistant Chief of Materiel Division, War Department, Wright Field, Dayton, Ohio, 25 October 1941. TLS.

"Notes on conferences", from notebook prepared in Major Chidlaw's Office, 9 September 1941. TD.

Royce, Ralph, London, to Army Air Forces, Washington, D.C., 11 September 1941. TDS.

Self, Henry A., Director General, British Army Commission, Washington, D.C., to H. L. Stimson, Secretary of War, War Department, Washington, D.C., 22 September 1941. TLS.

--------., Director General, British Air Commission, Washington, D.C., to Henry L. Stimson, War Department, Washington, D.C., 14 October 1941. TLS.

Stimson, Henry L., Secretary of War, to Sir Henry Self, British Air Commission, Washington, D.C., 9 October 1941. TLS.

Towers, J. H., Chief of the Bureau of Aeronautics, Navy Department, Washington, D.C., to Chief of the Air Corps, U.S. Army, 20 February 1942. TLS.

5.2.2 NATIONAL ARCHIVES RECORD CENTER, SUITLAND, MARYLAND

5.2.2.1 RECORD GROUP 255 GENERAL RECORDS (DECIMAL FILES) 621-623.1

Hunsaker, Jerome C., [Washington, D.C.], to George W. Gray, New York, N.Y., 4 September 1946. TLS.

Lewis, George W., Director of Aeronautical Research, to George W. Gray, New York, N.Y., 12 August 1946. TLS.

Littell, R. E., Washington, D.C., to Dr. George Lewis, 9 August 1946. TLS.

5.2.2.2 RECORD GROUP 255 GENERAL RECORDS NASA-NACA GENERAL CORRESPONDENCE 1915-1942 NUMERIC FILE 21-22 TO 21-24 BOX 112

Jacobs, Eastman N., Principal Aeronautical Engineer, Langley Field, Va., to Engineer in Charge, 16 May 1942. TLS.

Kemper, Carlton, Langley Field, Va., to [Engineer-in-Charge], 4 December 1939. TLS.

Lewis, George, W., Director of Aeronautical Research, Washington, D.C., to Langley Memorial Aeronautical Laboratory, 22 April 1940. TLS.

Miller, Elton, W., Head Mechanical Engineer, Langley Field, Va., to Engineer in Charge, 13 May 1942. TLS.

Pinkel, Benjamin, Associate Physicist, Langley Field, Va., to [Power Plants Division], "Memorandum for Chief Power Plants Division," 15 February 1940. TDS.

--------., Associate Physicist, Langley Field, Va., to [Power Plants Division], "Memorandum for Chief Power Plants Division," 3 April 1940. TDS.

Reid, H. J. E., Engineer-in-Charge, Langley Field, Va., to NACA [Washington, D.C.], 10 April 1940. TLS.

--------., Langley Field, Va., to NACA [Washington, D.C.], 13 April 1940. TLS.

--------., Engineer-in-Charge, Langley Field, Va., to George W. Lewis, Director of Aeronautical Research, Washington, D.C., 16 May 1942. TLS.

--------., Engineer-in-Charge, Langley Field, Va., to NACA, 18 May 1942. TLS.

Sherman, Albert, Assistant Aeronautical Engineer, to Langley Memorial Aeronautical Laboratory, 11 April 1940. TLS.

--------., Assistant Aeronautical Engineer, Langley Field, Va., to [Engineer in Charge], 11 April 1940. TLS.

--------., Assistant Aeronautical Engineer, Langley Field, Va., to Engineer in Charge, "Memorandum for Engineer-in-Charge," 1 May 1942. TDS.

Theodorsen, Theodore, Head Physicist, Langley Field, Va., to [Engineer-in-Charge], 19 March 1940. TLS.

Wyld, James H., Junior Aeronautical Engineer, Langley Field, Va., [Engineer-in-Charge], 23 January 1940. TLS.

--------., Junior Aeronautical Engineer, Langley Field, Va., to [Engineer in Charge], "Memorandum for Engineer-in-Charge," 23 January 1940. TDS.

5.2.2.3 RECORD GROUP 255 RECORDS RELATING TO NACA COMMITTEES AND SUBCOMMITTEES 117.25

Bush, Vannevar, Chairman NACA, to Dr. Jerome C. Hunsaker, Cambridge, Mass., 10 March 1941. TLS.

--------., Chairman NACA, to Rear Admiral John H. Towers, Bureau of Aeronautics, Navy Department, Washington, D.C., 10 March 1941. TLS.

--------., Chairman NACA, Washington, D.C., to Major H. H. Arnold, Office of Chief of Air Corps, War Department, Washington, D.C., 10 March 1941. TLS.

--------., Chairman NACA, [New York], to W. F. Durand, Stanford University, California, 18 March 1941. TLS.

--------., [New York], to W. F. Durand, Stanford, California, Telegram signed. 18 March 1941.

--------., Chairman NACA, [Washington, D.C.], to W. F. Durand, Stanford, California, 21 March 1941. TLS.

--------., [Washington, D.C.], to Dr. Charles G. Abbot, Smithsonian Institution, Washington, D.C., 24 March 1941. TLS.

--------., Chairman NACA, to Dr. George J. Mead, West Harford, Conn., 29 March 1941. TLS.

Committee on Power Plants for Aircraft, Washington, D.C., to Executive Committee, NACA, Washington, D.C., 11 February 1941. TLS.

Lewis, George W., Director of Aeronautical Research, to Vannevar Bush, Washington, D.C., 15 March 1941. TLS.

--------., Director of Aeronautical Research, to R. S. Buck, Pratt & Whitney Aircraft, East Hartford, Conn., 31 March 1941. TLS.

5.2.2.4 RECORD GROUP 255 RECORDS RELATION TO NACA COMMITTEES AND SUBCOMMITTEES 118.24-118.33

Industry Consulting Committee, Washington, D.C., "Minutes of First Meeting of Industry Consulting Committee," 26 September 1945. TD.

5.2.3 NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Documents found in a cabinet put together by Alex Roland in the History Office of NASA, Reporters Building, Washington, D.C.

Lombard, Albert E., Engineering Consultant, Consolidated Vultee Corporation, San Diego, Cal., to James W. Mead, Chairman of Special Committee Investigating the National Defense Program, Washington, D.C., 16 January 1946. TLS.

Raymond, A. E., Vice President-Engineering, Douglas Aircraft Company, Inc., to George Meader, Chief Counsel, Mead Committee, Washington, D.C., 7 January 1946. TLS.

Schoults, Roy D., Vice President-Engineering, Bell Aircraft Corporation, to James Mead, Chairman of Special Committee Investigating the National Defense Program, Washington, D.C., 14 January 1946

5.3 SECONDARY SOURCES

Bower, Tom. *The Paperclip Conspiracy: The Hunt for the Nazi Scientists.* Boston: Little, Brown Company, 1987.

Boyne, Walter J. and Donald S. Lopez, eds.. *The Jet Age: Forty Years of Jet Aviation.* Washington, D.C.: Smithsonian Institution Press, 1979.

Chandler, Alfred, D. Jr. *Strategy and Structure: Chapters in the History of the Industrial Enterprise.* Cambridge, Mass.: M.I.T. Press, 1962.

--------. *The Visible Hand: The Managerial Revolution in American Business.* Cambridge, Mass.: The Belknap Press of Harvard Universtiy Press, 1977.

Constant, Edward W., II. *The Origins of the Turbojet Revolution.* Baltimore: The Johns Hopkins University Press, 1980.

Dupree, A. Hunter. *Science in the Federal Government: A History of Policies and Activities to 1940.* Cambridge, Mass: The Belknap Press of Harvard University Press, 1957.

Ferrell, Robert, H. ed. *The Eisenhower Diaries.* New York: W. W. Norton & Company, 1981.

Goddard, Robert, H. *Rocket Development: Liquid-Fuel Rocket Research 1929-1940.* New York: Prentice-Hall Inc., 1948.

Hanle, Paul, A. *Bringing Aerodynamics to America.* Cambridge, Mass.: The M.I.T. Press, 1982.

Holley, Irving, Brinton, Jr. *Buying Aircraft: Materiel Procurement for the Army Air Forces.* Office of the Chief of Military History Department of the Army: Washington, D.C., 1964.

Kevles, Daniel, J. *The Physicists: The History of a Scientific Community in Modern America.* Cambridge, Mass: Harvard University press, 1987.

Koppes, Clayton R. *JPL and the American Space Program: A History of the Jet Propulsion Laboratory.* New Haven: Yale University Press, 1982.

Lasby, Clarence G. *German Scientists in America: Their Importation, Exploitation, and Assimilation, 1945-1952.* Ph. d. Dissertation, University of California at Los Angeles, 1962.

Marcus, Alan I., and Howard P. Segal. *Technology in America: A Brief History.* San Diego: Harcourt Brace Javanovich Publishers, 1989.

Ordway, Frederick I, III, and Mitchell R. Sharpe. *The rocket Team.* New York: Thomas Y. Crowell, Publishers, 1979.

Pursell, Carroll W., Jr. *Technology in America: A History of Individuals and Ideas.* Cambridge, Mass.: the M.I.T. Press, rpt. 1986.

Rae, John, B. *Climb to Greatness: The American aircraft Industry, 1920-1960.* Cambridge, Mass.: The M.I.T. Press, 1968.

Roland, Alex. *Model research: The National Advisory Committee for Aeronautics 1915-1958.* Washington, D.C.: National Aeronautics and Space Administration, 1985.

Schlaifer, Robert *Development of Aircraft Engines.* Andover, Mass.: Andover Press, LTD., 1950.

Struhlinger, Ernst, Frederick I. Ordway, III and others. *Astronautical Engineering and Science: from Peenmunde to Planetery Space..* New York: McGraw-Hill Book Company, Inc.?

Von Braun, Wernher *Space Frontier.* New York: Holt, Rinehart and Winston, 1967.

Von Braun, Wernher and Frederick I. Ordway III. *The Rocket Red Glare.* Garden City, New York: Anchor Press/Doubleday, 1976.

--------. *Space Travel: A History..* 4th ed.New York: Harper & Row Publishers, 1985

Von Karman, Theodore, Lee Edson. *The Wind and Beyond.* Boston: Little, Brown and Company, 1967.

5.4 ARTICLES

Hansen, James, R., "The Cowling Story at Langley Laboratory 1926-1936," *Aerospace Historian* 32 3 (Fall, September 1985): 161-70.

Roland, Alex, "The National Advisory Committee for Aeronautics," *Prologue* 10 2 (Summer 1978): 69-81.

Appendix A. THE WHITTLE ENGINE

A note on Appendix A: this series of documents is arranged in chronological order, and illustrates the different events that led to the delivery of the Whittle engine to the United States.

Paraphrase of a Secret Cablegram. Received at the War Department 11:43 AM 21 July 1941. From M/A London, England July 21 1941 to MILID.

This message is from Royce for General Arnold Reference your 1730, advised by MAP under date of July 19 that Rolls Royce representative at Packard, Mr. Ellor, will be returning in about two weeks to USA with complete data on Merlin 60 and 61 engines which are to be turned over to the Army Air Corps. This is the Merlin 20 with two stage two speed supercharger. Have again been informed by MAP that the British Air Commission at Washington has been authorized to release complete information on Whittle.

Lee

Routing and Record Sheet. Subject: Jet Propulsion (Whittle Engine) From Major Higgs to Major Beebe, 8/5/1941.

Major Chidlaw called and said that Major Keirn is going to England and one of the things he is interested in is the Whittle engine. Major Chidlaw understands that General Arnold has some information on this engine. Will you please call Major Chidlaw and let him know what you know about it.

J.H.H.

Subject: Report Whittle Engine to: Major General H. H. Arnold, Chief of the Army Air Force Through Brigadier General Ralph Royce, Military Attache for Air, London, England. 16 August, 1941.

1. Pursuant instructions contained in your Cable No. 31, Spobs, dated July 18, 1941 a special committee consisting of Colonel A. J. Lyon, Major C. Brandt and Mr. R. Schoults had made a study of the Whittle Engine.

2. Reports, specifications and drawings of the Whittle Engine and Gloster Whittle airplanes listed in enclosure No. 1 are being forwarded by separate cover. A duplicate set of these data are being furnished the British Air Commission in Washington by the The Ministry of Aircraft Production, London, England. A brief resume of the Whittle Engine Project is attached. (Inclosure No. 2)

3. There is nothing obscure or unusual in the manufacturing methods required. Accordingly there is no reason why these engines could not, with suitable priorities, be manufactured to present drawings in the U.S.A., G.E. or other plants. The steel is special but if we have no equivalent or better steel we could manufacture to British specifications. It is likely, however, that our people would prefer to redesign in detail to permit ease of manufacture with out tools and methods. This can be determined by placing an "educational order" for a limited number of units of the W-2-B Engine released for production by the British.

4. *Recommendations*: It is recommended:

a. That an "educational order" be placed at once for the production of a limited number of Model W-2-B Whittle Engines.

b. That detailed design of the turbine be modified to facilitate quantity production.

c. That we obtain form M.A.P. the loan of the W1X unit for educational purposes. (Ship via air).

d. That Wing Commander Whittle be invited to the United States for consultation.

e. That the Whittle principle form the basis of a major development project.

[Points 5 and 6 did not appear in the documents.]

7. Major Keirn is studying other projects in early development stages in England. Plans for carrying out recommendations "e." above, should be deferred.

8. All members of the committee concur.

A. J. Lyon,
Colonel, A.C.

American Embassy Office of Special Army Observer, 20, Grosevernor Square, W.1 London, England. *Report on Visit to Power Jets, Lutterworth, England August 28-31, 1941*

A. PURPOSE. To report discussion with Wing Commander Whittle on the development of the Whittle Engine and observations of engine tests. (Drawings and data on Whittle Engine have been forwarded and no description of engine will be made herein.)

B. *FACTUAL DATA.*

1. *Personnel and plant* After a brief interview with Wing Commander Whittle and Wing Commander Lee at Brownover Hall, the dispersion point for Power Jets design section, a visit was made to the plant at Lutterworth where the experimental work, construction of experimental models, modifications, and testing of experimental models are accomplished.

The Lutterworth plant at present consists of a number of old frame structures housing shop and offices, three new test chambers in a separate brick structure, and a building under construction which will have bombproof, or more accurately, blast-proof rooms for engine storage, etc. Power Jets employs about 300 people. The engineering staff is composed of young engineers whom apparently have been carefully selected. A splendid spirit of cooperation and enthusiasm exists.

Wing Commander Whittle has avoided any mention of his personal interest in Power Jets as a company, referring to the company as a design section for the

M.A.P. He stated that their function at the present time is purely as a design and experimental section, where designs are developed and modifications tested. Production is handled by M.A.P. and the Rover Company has been designated to produce the W-2-B Whittle engine. Production of the first hand-made units are under way at the present time. The delivery of the first 30 should be completed by March 1942 with a production rate of 20 a week thereafter.

2. *Test Chambers. a.* The plant has three test chambers equipped with engine mounts and the required equipment for testing the Whittle engine. No dynamometers or motors for testing the components parts, i.e. the compressor or the turbine separately are available.

b. The test chamber and engine mount for testing the Whittle engine is quite simple. The motor is mounted on a frame which is suspended from the ceiling by four rods with ball bearing rod ends. Side motion is controlled by two horizontal parallel rods likewise with ball bearing rod ends and connecting the engine mount frame to a rigid framework extending up from the floor. This provides free fore and aft movements of the frame. The fore and aft thrust of the motor is then measured [missing words] a hydraulic cylinder and calibrated pressure gage. All fuel, manometer and thermocouple connections to the engine are, of course, flexible.

c. No ducts are used to supply air to the Whittle engine. It is therefore necessary to measure airflow into the test chamber. The chamber is air-tight with a large venturi entrance at one end of the room. The throat was square and about two feet on a side. The venturi was calibrated by traversing the throat with petot tubes. They believe their airflow measurements are in error less that 1%.

The engine exhaust nozzle extends out through the back wall of the test chamber. An air seal is provided by a fabric skirt clamped to the exhaust pipe and to the chamber wall. Slack is provided to permit sufficient free movement of the engine to measure thrust.

The operating room is adjoining the test chamber, (one test chamber on each side of common operating room) and is effectively soundproofed.

3. *Tests observed on W1X engine. a.* The W1X engine is generally similar to the engine which was flown in the single engine Gloster airplane (E28/39), except for air cooling of bearings instead of the water cooling used in flight engine. Owing to some cracked turbine blades, the R.P.M. was restricted to 12,000 at which speed the engine only produced 300# thrust. Tests being conducted at time of visit consisted in starting tests.

b. The first starting mechanism consisted of a solenoid switch with double winding, one coil being in the starting circuit, the other in the starting motor circuit. On closing the starting with a push button, the solenoid switch was held in contact by starter motor current until the turbine was brought up to about 1800 R.P.M., at which time the engine was capable of self operation. As turbine speed increased it overruns the starter on an over-riding clutch and the current consumption of the starting motor, when the load of turbine is removed, is reduced to a value which permitted a spring to disengage the solenoid switch. A spark coil and 2 spark plugs were incorporated in sane circuit. These provide initial ignition. Combustion is continuous thereafter. Starting normally took place in 6 to 10 seconds.

c. Second starting system. In order to prevent continuous overload of the starting motor in case the engine fails to fire, a second test was made with a time switch identical with those employed by automotive manufacturers in England for turning signals. This switch automatically breaks the starting circuit after a time interval of approximately 17 seconds. It was proposed also to try a dash pot type of push switch similar to the timing devices used on cameras.

d. Operation of fuel system. Fuel is injected into the combustion chambers by spray nozzles or burners in which is incorporated a spring loaded piston which uncovers a series of ports as the fuel pressure is increased, thereby giving a fuel flow approximately proportional to pressure. As the rate of fuel injection is increased, the resultant rise in combustion chamber temperature results in an increase in turbine power and an increase in turbine speed until a balance between turbine power output and the power absorbed by the compressor is reached. Consequently, speed is controlled by the fuel pressure.

e. The fuel system consists of a gear fuel pump with relief valve set for 450# and a needle valve operated by the throttle. For starting purposes and also to keep the engine running when the throttle is closed at a speed from which it can be accelerated quickly by opening the throttle, a bipass around the throttle needle valve is used with a reduction valve which provides the fuel pressure at the burners required for 4000 to 6000 R.P.M.

f. Several designs of automatic altitude control devices are under consideration including a modified Hamilton Standard propeller governor which will govern turbine speed, a manual control to the governor replacing the throttle. This arrangement functioned satisfactorily when governor was supplied with engine oil under constant pressure, but it was thought desirable to operate the unit from fuel pressure. When the latter was tried, instability is necessary.

g. From the tests witnessed it was concluded that, although further development of automatic control devices will be necessary, the problem is not a difficult one. Starting is easy, and apparently no extensive warm-up period is necessary.

4. *W2MKIV*. *a*. The W2MKIV engine is the test engine and prototype of the production engine which is known as the W-2-B. It differs from the W-2-B in that it has a different accessory section. Although the W-2-B is the production engine, certain design changes will undoubtedly be made before actual production models are ready for delivery. When Rover was given the production of the W-2-B engine, they were authorized to make no changes involving aerodynamic or thermodynamic characteristics of the engine. The Ranger W-2-B engine will therefore be similar to the W-2-B as designed by Power Jets but will incorporate minor modifications; notably different bearing arrangements and a different accessory drive section.

b. Tests of the W2MKIV were unsatisfactory. Surging of the compressor was occurring and modifications of the diffusor section were underway in an attempt to overcome the difficulty. The diffusor section of the W-2-B and W2MKIV consists of a cascade of modified airfoil sections transposed to a circle. The air is discharged radially from the diffusor instead of approximately tangentially as in the W1X engine and other conventional designs. Blades are stampings and held between two plates by two rivets formed integrally with the blade. It was at first supposed that the leading edges of the blades were bending and reducing the entrance area. Thinning the blades in an attempt to increase this area resulted in reducing the speed at which surging began. (Surging began at 14,000 R.P.M. on the original design and subsequent modifications brought the surge down to 8,600. On one test, the inner row of blading was removed with the result that surging started at 4000 and the temperature at turbine blades went up to 800o C. (600o C. is design operating temperature.).

c. Wing Commander Whittle pointed out that the computed operational conditions of the compressor lie very close to the computed surge conditions for the compressor at mid-range speeds. He was of the opinion that, were it possible to pass through the mid-range, (10,000 to 14,000 R.P.M.) the engine would operate satisfactorily at rated speed (16,500). However, the surge was sufficiently violent to render it unsafe to attempt to check this theory.

d. Modifications are in progress and further tests will be made, using diffusor vanes with more carefully formed leading edges, and with a diffusor section incorporating fewer vanes.

e. Efficiencies determined for the compressor for the runs accomplished indicated an average of 75%. An efficiency of 78% was computed in the design of the blower.

5. *General comments on W-2-B design. a.* Every effort had been made to keep the weight of the W-2-B unit as low as possible. Magnesium is used extensively, all parts not being subject to severe heat or high loads on thin sections being magnesium. A material known as "starblade" is used for heat resistant parts except for turbine blading, nozzle box which are "Rex 78", and the inner combustion chamber flame tube which is made of materiel similar to that used in electric heater filaments. The combustion chambers are made of very thin sheet (o.016) and electrically welded where practicable with overlapping spot welds. No difficulty has been experienced with such thin sheets to date, although probably no combustion chamber has had more than 100 hours operation at this time.

b. The material used in the turbine blades, "Rex 78", has set the design characteristics of the W-2-B with regard to operating temperature and R.P.M. The blade stress is approximately 23,000 lbs/sp. in. at the operating speed (16,500 R.P.M.). At 600o C. and at the design stress, this material creaps approximately 1% per 1,000 hours. It was pointed out that a material capable of operation at higher temperatures but of the same or slightly lower creap strength might offer some possibilities of thermodynamic improvement of the engine, but that owing to the single stage design of the Whittle engine, a material having a higher creap strength is very desirable. Wing Commander Whittle stated that a study could be made to give the desired characteristics of a material for the turbine blades but that they were unable to spend the time on such a study at present.

c. Much bearing trouble was experienced with the first Whittle engines. This trouble has been eliminated by careful design and better lubrication in present models. The present bearings are lubricated by light oil, metered through a spray tube at one end of the bearing cage, being fed about a pint per hour. Air is blown across the end of the spray tube and against the bearing race. This provides a fine continuous spray of oil to the bearings. An oil pressure of 4 pounds is used and a sight gage used to adjust the flow to the correct amount.

d. The following factors were pointed out as being of vital importance in securing satisfactorily performance of the high speed bearings:

(1) Cages must be held firmly on shaft and in case bosses but must not be clamped to the extent of distortion of races.

(2) The proportion of oil and air is critical, too much oil causing overheating, and too much air having a tendency to blow oil off bearing allowing it to run dry.

(3) Air and oil must be very carefully filtered. Air is filtered by a felt pad. Oil filter is 0.0015 mesh.

(4) General arrangement of bearings and air and oil lines are shown in sectional drawings of Whittle W-2-B engine which had previously been submitted.

e. The combustion chamber design used at present is satisfactory from the combustion standpoint. The pressure drop is between 1 1/2 and 2 1/2 lbs. per sp. in. and is higher than desirable.

f. Difficulty was experienced with the first double entry compressor due to one side of the impeller "hogging" the load. It was found necessary to operate in such a range that a slight increase in flow resulted in a drop in pressure. Under these conditions stable operation may be attained.

6. *Comparison of Whittle Type engines with conventional power-plants.*

a. Figure A shows a graph of engine installed weight plus weight of fuel plotted against endurance, for three hypothetical engine installations. The conventional engine installation is based on an assumed installed weight. A thrust efficiency of 72% was assumed as 12% of design gross weight.

b. The weight of the jet propulsion units is based on the design weight of two units both of which had single stage centrifugal compressors and single stage turbines and wight approximately 20 lbs. per lb. of air handled at sea-level. The amount handled at altitude was assumed to be proportional to density. Both jet propulsions were assumed to have 85% combined turbine-exhaust nozzle efficiency.

c. Some reduction in airframe weight principally due to shorter landing gear as well as a probable reduction in drag due to the jet may be claimed for the jet propulsion units but has not been considered in chart.

It may be seen that even the less efficient jet propulsion unit will have a 36% greater endurance at full speed (500 M.P.H.) assuming that the conventional engine could be operated continuously at military power. This of course is contingent upon the ability to install sufficient tankage. It will be noticed that for the same tankage, the endurance will be slightly less but the military load will be increased 77%.

d. The dotted lines represent cruising at 60% power or 420 M.P.H., after 15 minutes operation at military power. The inability of the jet propulsion units to compare favorably with the conventional engine under cruising conditions is very apparent. The more efficient jet propulsion unit apparently equals the conventional airplane but it should be observed that to do so the fuel capacity of the airplane must be increased 100%, which would, in all probability be impossible in a 500 M.P.H. airplane.

e. Figure A is based on calculations of jet performance and assumed weights. Certain simplifying assumptions were made in the belief that errors introduced would be negligible as compared with assumed efficiencies. For this reason the graph is intended as a qualitative study to point out the relative advantages of the Whittle engine rather than to give any significant figures on performance.

f. The chart points out clearly that the advantage of the jet propulsion engine is essentially its light weight. It is clear that for a given design, an improvement in efficiency is quite beneficial. However, an improvement in efficiency that may be gained by a more complicated engine, as for example, double staging of turbine or compressor, may or may not be warranted, depending upon the weight increase.

C. *Conclusions*:

1. It appears probable that, contingent upon straightening out the compressor difficulties in the W-2-B engine which may involve some changes in compressor cases, or some sacrifice of efficiency, the Whittle W-2-B engine offers a solution to the power-plant problem of the very high speed interceptor type airplane.

2. For endurance under 2 hours the extreme light weight of the engine compensates for the additional fuel consumption, provided space if available for the fuel required. This comparison is based on the use of full throttle and military power in the conventional airplane. For patrol work, where the consumption of the conventional engine may be greatly reduced, the jet power-plant shows up very poorly as the efficiency drops with reduction of speed. Consequently, the Whittle engine should be utilized only for the extreme high speed aircraft intended to operate at high speed for moderate periods of time.

3. The airplane must be suitable for the jet propulsion power-plant. This probably means aircraft designed specially for this type power-plant.

4. The production costs of the Whittle engine should be but a small fraction of the cost of the conventional engine and propeller.

5. The installation of the Whittle engine is extremely simple and the cooling and oil system so troublesome in conventional installations are not present.

6. Landing gear weight is reduced.

7. The high velocity jet will require the exercise of great care in ground handling and will undoubtedly make taxying difficult and possibly dangerous to other aircraft or ground personnel.

8. Due to the low thrust as compared with a propeller at taxying speeds, operation on soft fields will probably be difficult.

9. Before the W-2-B engine can be considered as a satisfactory engine for tactical aircraft, the compressor surging problem must be solved. It is also essential that some form of type test or endurance test be conducted to determine its mechanical suitability. Although it is difficult to predict how many changes may be necessary in the W-2-B engine before it will operate satisfactorily, it appears probable that the Whittle engine will be in use by early spring of 1942.

/s/ D. J. KEIRN

Major, A. C.

Memo from Col B. W. Chidlaw to General Echols, approximately 4 September 1941.

1. Build 15 *engines*

   a. Cable to Lyon for full production details.

   b. Cable to England for an engine and one of the test airplanes.

   c. Cable to England for Whittle, if possible, and his key engineer.

   d. Definite authorization to the U.S. Government to reproduce the the engine in the U.S.

   e. Obtain highest priority for materials, etc.

2. Highest priority for engineers on project on our ferry service.

3. Present drawings now available to G.E. primarily engine drawings.

4. Secrecy to include not only access to master drawings but also conversations about engine except amongst those intimately associated with it.

5. Call this Supercharger Type I.

6. Airplane.

a. Twin engine combat interceptor type since power output now is insufficient to take care of single engine combat types.

b. Build three of them.

c. Tentatively select Bell due to proximity to General Electric with Douglas as alternate.

7. Selection of officer where one job is to accelerate this project. Echols recommended Keirn.

8. Get Bell and Woods here tomorrow to meet with Mr. Schultz, and Gen. Echols with Gen. Arnold.

Cable sent by General Henry H. Arnold to Lt. Col. Moore-Brabizon, MAP London, 4 September 1941.

At conference this date decision reached to produce Whittle engine in this country. Initial design planned around a two engine interceptor type. U.S. Air Force desire to proceed with this project with greatest possible speed and for this reason it is requested that complete repeat complete detail production drawings be furnished to us at earliest possible date. Request also that we be furnished one complete engine already built and one of the single engine airplanes which this office understands can be made available and that both engine and airplane be shipped to this country at the earliest possible date. If possible it is desired that Whittle and such key engineering personnel as may be spared be sent to this country to expedite the initiation of this project. Definite authorization should be furnished to the US Government covering reproduction rights in this country.

"Notes on conferences" from notebook prepared in Major Chidlaw's Office. 9 September 1941.

To furnish brief resume of the Type I Supercharger (Whittle) and the XP-59A (Bell) airplane projects.

On Thursday, September 4, 1941, an initial conference was held in General Arnold's office regarding the feasibility and desirability of going into immediate production in this country on the Whittle engine project, and a determination as to which airplane manufacturer was best qualified at this time to carry out this jet propulsion development in conjunction with the General Electric Company.

The preliminary conference called by General Arnold was attended by General Spaatz, General Echols, Lt. Col. Gardner, Majors Chidlaw, Brandt, Irvine, and Messrs. A. R. Stevenson, Jr., Engineering Assistant; S. R. Puffer, Design Engineer on Turbo Installations; R. C. Muir, Vice-President in Charge of Engineering; and D. R. Shoults, Industrial Research Department, all of the General Electric Company.

Certain preliminary data and drawings which had been furnished to General Arnold were briefly examined in the presence of the General Electric people and determination was reached that it would be possible for them, *were the production drawings made available to them from England in the immediate future*, to produce a duplicate engine in approximately six months period with two more engines to be produced in an additional two months period, the latter two engines to be such as to be ready for installation in an actual aircraft. Various details of the method of building, method of procuring data from England, etc., were discussed.

In his opening remarks, General Arnold stressed the vital necessity for keeping everything, in any way remotely connected with this project, *absolutely* secret, due to the political and economic repercussions which might obtain, should the entire project prove successful. It was decided at that time to formulate a cable to be dispatched immediately to England (Moore-Brabizon) to obtain all the information. A copy of this cablegram is in the files.

It was likewise decided to invite Mr. Bell of the Bell Aircraft Company to Washington the following morning, for a similar conference in regard to the aircraft end of this entire development. On Friday, September 5th, Mr. Bell and his Chief Engineer, Mr. H. M. Poyer, visited General Echols' office, where a preliminary meeting was held, everyone again cautioned as to the necessity for absolute secrecy, and the proposition was advanced to Mr. Bell as to his participation in this entire development from the aircraft end. After an hour's discussion, Mr. Bell stated his desire to participate in this project and arrangements were made for a conference at 2:30 that afternoon to meet in General Arnold's office.

This conference was held at 2:30 in General Arnold's office. Present were the following: General Arnold, General Spaatz, General Echols, General Kenney, Lt. Col. Carroll, Lt. Col. Gardner, Majors Chidlaw, Irvine, Brandt; Mr. D. R. Shoults, representing General Electric Company. At this conference, General

Arnold briefly reviewed the previous day's decisions and discussed the aircraft part of the deal. The final decisions arrived at were namely:

15 engines - to be built, designed as Type I

Supercharger Development.

3 airplanes - to be built, designated as XP-59A.

The Bell Aircraft Company and the General Electric Company are to work in very close collaboration on this project, taking such steps as may be necessary to enjoin secrecy throughout.

The Materiel Division was given the directive of preparing the contracts in such a way that secrecy could be maintained throughout all the negotiations. A procedure was worked up whereby all British information received in this country relative to this project, i.e., production drawings, materiel specifications, etc. etc., would be forwarded directly to the General Electric Company, which had accepted the responsibility for the secret reproduction of such drawings and other data as may be necessary to furnish to the Bell Company.

The particular drawings and data initially furnished directly to General Arnold were checked and authenticated by Mr. D.R. Shoults of General Electric and Major Chidlaw, and then turned over to Mr. Shoults (receipt in files).

General Arnold advised that in connection with the effort to maintain secrecy on this matter, he would take the necessary steps to see that this project was withdrawn from the program of the Durand (NACA) Jet Propulsion Committee.

The respective manufacturers then left to return to their home offices to work up their proposals relative to costs, additional facilities as may be required, machine tools, schemes for maintaining secrecy, etc.

A later conference is to be held in the Office, Chief of Materiel Division, to arrive at the ultimate details, when the Materiel Division at Wright Field has everything lined up.

Cablegram form General Ralph Royce, London, England to Army Air Forces, Washington, D.C., 11 September 1941.

Plan in substance following agreed upon by Lyon COQQ Linnell and Whittle pursuant you and our 38 PD (First) AW1 QQ engine for test will be immediately shipped PD It is probable thousand pounds will be knocked down into smaller crates feasible for handling in B24 USFC PD (Second) Every Rover production drawing available COMMA so marked as to indicate possible chances COMMA will be obtained for forwarding via ferry command about 14 days PD (Third) One engine with a mechanic will accompany engine PD (Fourth) Detailed parts COMMA W2B production engine also will be sent with production drawings COLAN total weight of shipment probably 400 pounds PD (Fifth) Production drawings complete for B1 in engine Gloster fighter will be sent should you so desire PD A single engine test airplane is not available just now owing to program for flight test COMMA since an accident here to such airplane might delay program very much not only in US but here PD Shipment of a prototype of the production article two engines fighter complete with production engine will agreed upon by minister COMMA to be available probably by May PD (SiQQth) Whittle with two to three engineers additional to the engineer and mechanic mentioned above to accompany engine will go to U.S. after the project gets under way and details of design have been cleared up in England PD

(Seventh) Reference rights of production COLAN the answer upon this detail is pledged for an early date PD Please advise earliest time ferry command can provide for transporting Whittle engine with two engineers PD Receipt your one siqqty of September tenth for acknowledgement.

ROYCE

Letter from Col. A. J. Lyon, American Embassy, London England, to General Arnold, 20 September 1941.

Dear General Arnold,

In keeping the preliminary survey of possibilities of Jet Propulsion I am greatly impressed with the amount of both basic and applied research that has been done on Jet Propulsion and Gas Turbine in England. The opinions of those who have studied and worked with these projects may be summed up by the unofficial statement made by Mr. Elliot, Chief Engineer of Production, Rolls Royce Company, that within ten years there will be no reciprocating gasoline engines produced for aircraft. Although I have not stated my personal views in an official communication, it would appear that in order for us to make up for time lost in this field of development we should seriously consider the following:

England does not have the money to put into adequate Jet Propulsion and Gas Turbine laboratories. We have. The power-plant laboratory, as we now know it, is inadequate for the gas turbine and Jet Propulsion engine.

Provisions for a Jet Propulsion and Gas Turbine laboratory at Wright Field should immediately be made as the problem is now primarily one of applied research.

The production of the Whittle engine should be considered as purely a stop gap measure.

Development programs should be initiated with the industry on a scale commensurate with our present program for the conventional type of engine development.

Goal for 4,000 and 5,000 horse-power units can be realized quicker with the jet propulsion and gas turbine than with the conventional type of engine, if all factors are to be considered, i.e. aircraft design high altitude performance, plumbing and accessories, cooling and propeller design.

The matter of collaborating with Rolls Royce will have to be very tactfully handled since this development is regarded as an important post-war production activity of the Rolls Royce Company. On the other hand, as I stated to Marshal Linnell, we cannot fit out sights, insofar as research and development is concerned, on the war ending in 1943

Major Keirn had performed a very important bit of work in analyzing the status of Jet Propulsion and Gas Turbine developments in England. However, it will be necessary for us to follow the developments here very closely and I hope that after we have gotten underway that he can return to England for another study tour in order to insure that we keep in step with progress in these developments.

A. J. Lyon

Letter by A. H. Self, Director General, British Air Commission, Washington, D.C., to H. L. Stimson, Secretary of War, Washington, D.C., 22 September 1941.

Sir,

I have the honour to refer to various conversations that have taken place with General Arnold and Colonel Larner regarding the development in the United States of the Whittle Engine and to say that the authority of the British Government has now been received for the release of all available information to you.

A portion of this information is already in the hands of General Arnold and subject to your approval, we will arrange to supplement it as necessary to General Arnold personally. Owing to the vest great degree of secrecy attaching to this information, I am to request that the same precautions may be applied as are applied to your own most secret developments.

As regards manufacture, the British Government desire to suggest, for your consideration at the appropriate time, the General Electric Company as suitable in view of their standing and their work on turbo-superchargers. They are appreciative, however, of the possibility that, in order to achieve rapid production, you may wish to consider the advisability of enlisting the co-operation of one of more of the main engine manufacturers. I should be grateful if you would inform me, in due course, of your decision on this subject, should it be decided to proceed with the manufacture in the United States.

In the event that manufacture, whether experimentally or otherwise, is decided upon, I should be grateful for your confirmation that the following arrangements (which are in accordance with those discussed in the correspondence stemming from our letters of December 13th, 1940, to you and to the Secretary of the Navy) would obtain.

1. As the information and drawings have been released by the United Kingdom Government and permission to manufacture had been given, in order to assist the joint defense plans of our respective Governments, it is agreed that its use will be limited to such purpose.

2. The above mentioned steps have been taken by the United kingdom Government in reliance upon the arrangements recently agreed between our respective Governments as to secrecy and as to the protection of commercial rights in respect of information and equipment exchanged; all such commercial rights relating to the apparatus and information now in question being hereby reserved.

3. It is agreed as a condition of the disclosure of the data and drawings that although manufacture and assembly of the apparatus may, if desired, be carried out in its entirety in one or more factories belonging to the approved firms, this will only be done under secret status by staff who have been engaged on secret United States projects for a number of years and whose background is known. Also that safeguards additional to normal inspection and security precautions will be applied.

4. It is further understood between us that except for the purpose of manufacture in the United States, the United States Government will not, without the previous concurrence of the United Kingdom Government, disclose or communicate to any third party (whether pursuant to the terms of any Licence Agreement or otherwise) particulars of the drawings and information disclosed or of the apparatus manufactured therefrom nor of any new invention or improvement which may come into their possession or control relating to such apparatus, or to any part of it, derived directly or indirectly from information disclosed by the United Kingdom Government. Also, that no technical or other expert, other than a United States citizen or a British subject (and in either case of known background), whom the United States Government may wish to call in to assist in the production of the apparatus, will be permitted to have knowledge of it without the prior consent of the United Kingdom Government.

I should appreciate your confirmation that the foregoing statement as to the terms of this Release meets with your approval. We should be glad, if so desired, to furnish any further clarification of the position which may be thought necessary.

I have the honour to be, Sir

Your obedient servant,

/s/ A. H. Self

Director General

Letter by Roderic Hill, British Air Commission, Washington, D.C., to General Henry H. Arnold, War Department, Washington, D.C., 29 September 1941.

Dear Arnold,

I have just heard from the Ministry of Aircraft Production that they are sending a Whittle W.I.X by Air consigned to Wright Field. It is said to be arriving about October 1st.

Two Power Jets Ltd. men are coming out, Mr. D. M. Walker, Chief Test Engineer, and Mr. G. B. Bozzoni, Experimental Fitter. I understand that Major Keirn, U.S. Army and Flight Sergeant J. A. King, R.A.F., are also coming.

Major J. N. D. Heenan, Chief of the Engine Development Section, British Air Commission, has been appointed to supervise our side of the work, and will be only too pleased to collaborate with such officers as you appoint.

Yours sincerely

Roderic Hill

Letter from General Henry H. Arnold, Chief of Army Air Forces, to Lt. Col. J. T. C. Moore-Brabizon, Minister of Aircraft Production, London, England, 30 September 1941.

Dear Moore-Brabizon,

The following letter will serve to furnish you a brief resume of the action we have taken to date, in this country, reference the reproduction and test of the Whittle W2B Supercharger project.

As you know, arrangements have been completed for the transportation to this country of one actual engine, together with complete production of drawings and material specifications. We have likewise requested additional information, such as manufacturing processes for certain main bearings, test specimens of the higher stressed parts, etc. etc. We have been advised that information on these items is being collected and will be forwarded as soon as it can be made available.

Letter by General Henry H. Arnold, Washington, D.C., to Colonel Alfred J. Lyon, London, England, 2 October 1941.

My dear Al:

Sometimes I wonder just what we should do to make it possible to keep our foreign observers informed of what is going on in the United States without such a great effort as is now necessary. Such action should be automatic and yet it is far from that. All this preparatory to my answering your letter of September 20th relative to the Whittle Engine.

For some time I have appreciated the tremendous importance of the Whittle Engine. As you will remember, when I returned from England in April, I brought back the story and immediately started the wheels of the scientific part of our show turning, slowly 'tis true but still turning. Since that time the wheels have been turning faster and faster until right now, as you know, we have General Electric working on the Whittle Engine and Bell working on the plane to put the Whittle Engine in, both coordinating their effort so that we have one project. We realize that this is just a stop gap and that it is not a production proposition. The production proposition will have to come along later. As a matter of fact, I gave instructions that the Whittle Engine would be completed in every detail so that we would have something that would work, and after they completed that article, they could go ahead at will in an endeavor to improve upon it and secure better design, better construction methods, or "what have you."

I was told in England in April that in ten years there wouldn't be any more poppet valves or, as a matter of fact, any type of gas engine as we now have in pursuit airplanes, and another five years would see the end of that type of engine in all types of aircraft. I must admit that I was not as enthusiastic about such a proposition as the advocates in England were. In my 30 years in aviation I have seen too many of these things come up that are going to completely revolutionize everything and do away with all heretofore existing forms of aircraft, so while I am enthusiastic, I am not super-enthusiastic.

I also agree with you that we will have to establish a jet propulsion and gas turbine laboratory, but I am not sure that it should go to Wright Field. As a matter of fact, I am not sure where it should go, so before I commit myself on that point, I want to do some more thinking on the subject. It might be better to have the N.A.C.A. establish such a laboratory for the benefit of the whole United States rather than have Wright Field start on such research and development work. However, I am open minded on the subject.

I do not believe that we are ready at this time to start a development program tending towards the production of the jet propulsion engine on the same scale as we now have for the conventional type of gas engine. I am of the opinion, however, that it will be much easier to reach the 4,000 to 5,000 horsepower with the jet propulsion and gas turbine that it will be with the conventional type of engine. Everything points in that direction. The gas turbine has everything to its advantage.

We have decided that Keirn will be put in charge of his development upon his arrival here we trust that he will be able to take advantage of all the information he has secured in England in order to expedite this work.

I hear from you occasionally and know that you are doing a grand job. I trust some time I will be able to get over and see you.

Give my kindest regards to all the bunch and tell them we are endeavoring to keep our organization on an even keel and build it up so that we will have an outfit that can perform "honest-to-God" combat missions if and when called upon.

Sincerely,

H. H. ARNOLD,

Major General, U.S.A.,

Deputy Chief of Staff for Air.

Letter by Henry L. Stimson, Secretary of War, Washington, D.C., to Sir Henry Self, Director General, British Air Commission, Washington, D.C., 9 October 1941.

Dear Sir,

Reference your letter of September 22, 1941, in the matter of the reproduction and development in the United States of the W2B supercharger in furtherance of the joint defence plans of our respective Governments, and in confirmation of the conditions imposed as a prerequisite to the release of full details in respect there to, the following arrangements and agreements shall apply:

1. As the information and drawings have been released by the United Kingdom Government and permission to manufacture has been given, in order to assist the joint defence plans of our respective Governments, it is agreed that its use will be limited to such purpose.
2. The above mentioned steps have been taken by the United Kingdom Government in reliance upon the arrangements recently agreed between our respective Governments as to secrecy and as to the protection of commercial rights in respect of information and equipment exchanged; all such commercial rights relating to the apparatus and information now in question being hereby reserved.

3. It is agreed as a condition of the disclosure of data and drawings that although manufacture and assembly of the apparatus may, if desired, be carried out in its entirety in one or more factories belonging to the approved firms, this will only be done under secret status by staff who have been engaged on secret United States projects for a number of years and whose backgrounds is known. Also that safeguards additional to normal inspection and security precautions will be applied.

4. It is further understood between us that except for the purpose of manufacture in the United States, the Unites States Government will not, without the previous concurrence of the United Kingdom Governments, disclose or communicate to any third party (whether pursuant to the terms of any License Agreement or otherwise) particulars of the drawings and information disclosed or of the apparatus manufactured therefrom nor of any new invention or improvement which may come into their possession or control relating to such apparatus, or to any part of it, derived directly or indirectly from information disclosed by the United Kingdom Government. Also, that no technical or other expert, other than a United States citizen or a British subject (and in either case of known background), whom the Unites States Government may wish to call in to assist in the production of the apparatus, will be permitted to have knowledge of it without the prior consent of the United Kingdom Government.

Negotiations will ensue forthwith with the General Electric Company with a view to the expeditious production of the referenced element, and in due course with selected engine and/or aircraft manufacturer under conditions of secrecy comparable to your own and calculated to safeguard the development against disclosures of any information to unauthorized persons.

You are, of course, aware that developments of this general character have been in course by this Department and other agencies in this country, both public and private. Accordingly, this Agreement must be deemed to relate to the Whittle development and nothing contained herein shall be construed to limit in any way the right of freedom of action in respect of such parallel developments now under way in this country, or any improvement therein or the ultimate commercial use

It is desired to assure you of the full cooperation of this Department in the thorough exploitation of the disclosure in contemplation and the early application of any improvements in aerial operations resulting therefrom.

Very sincerely yours,

/s/ Henry L. Stimson

Secretary of War.

Letter by Henry Self, Director General, British Air Commission, Washington, D.C., to Henry L. Stimson, Secretary of War, Washington, D.C., 14 October 1941.

Dear Sir,

I have to acknowledge and thank you for your letter of October 9th in regard to the production and development in the United States of the W-2-B supercharger.

The conditions and arrangements applying to the release of full details in respect thereto are noted, and the co-operation of the War Department in this matter is very much appreciated.

We are appreciative of the reason underlying the proposals in the penultimate paragraph of your letter and do not see any difficulty in regard thereto.

Yours very sincerely,

H. Self

Letter by Jerome C. Hunsaker, National Advisory Committee for Aeronautics, Washington, D.C., to Henry H. Arnold, Deputy Chief of Staff for Air, War Department, Washington, D.C., 13 October 1941.

Dear General Arnold,

This letter is in response to your request of February 25, 1941, to the National Advisory Committee for Aeronautics, regarding jet propulsion of airplanes.

On receipt of your request, a Special Committee was appointed under the chairmanship of Dr. W. F. Durand, including Brigadier General C. P. Echols, Captain S. M. Kraus, Dr. Hugh L. Dryden of the Bureau of Standards, Professor A. G. Christie of Johns Hopkins University, Professor C. Richard Soderberg of the Massachusetts Institute of Technology, Dr. L. W. Chubb of Westinghouse Electric and Manufacturing Company, Mr. R. A. Allen of Allis Chalmers Manufacturing Company, and Dr. A. R. Stevenson, Jr., of the General Electric Company. This committee has held frequent meetings and has caused to be made investigations into several aspects of the general problem.

Letter by Gen. Henry H. Arnold, War Department, Office of the Chief of Staff, Washington, D.C., to Major Donald J. Keirn, Wright Field Ohio, dated 15 October 1941.

Look over the attached and tell me what you think of it in comparison with the Whittle Engine.

H. H. ARNOLD
Major General, U.S.A.
Deputy Chief of Staff for Air

Letter by J. C. Miller, Manager, Aviation Division, General Electric Company, Schenectady, N. Y., to Assistant Chief of Materiel Division, War Department, Air Corps Materiel Division Wright Field Dayton, Ohio. 25 October 1941.

SUBJECT: Gas Turbine Power Plant for Aircraft Propulsion

OUR REFERENCE: GO-18350

Gentlemen:

Confirming recent conference between Col. F. O. Carroll and Col. E. R. Page and representatives of this Company, we submit herewith proposed specifications GO-18350 outlining construction and preliminary tests of a gas turbine power plant for aircraft.

Our price for the construction and test of the components parts of a gas turbine unit as covered by that part of the enclosed specifications up through paragraph 8 under the heading, "Specific Requirements" is $320,000 net f.o.b. Lynn, Mass.

Our price for the ground tests and reports as outlined in paragraph 9 through 14 under the heading "Specific Requirements" is $95,000 net f.o.b. West Lynn, Mass. This price is based on the assumption that any contract resulting from this proposal will include the following clause:

"In the event of the failure of any part of the equipment called for during the tests to be conducted under the terms of this contract, such parts shall be replaced or, if deemed necessary by the contractor, redesigned and replaced. The cost of such replacement and such design if necessary shall be borne by the Government. The cost for such replacement and/or redesigned parts, shall be negotiated between the parties hereto at the time same shall become necessary."

We anticipate that analytical design study can be completed and layout drawings submitted for release sixty days after date of contract. We expect that the completion of the test unit to the point of starting laboratory tests can be made in 300 days after release of layout drawing. We estimate that test covered by Item #2 above can be complete to the point where performance of the unit is established or major changes of design are indicated in sixty days after completion of the test unit and that the test report as well as proposal for the next step in the program can be completed in thirty days after the completion of the tests themselves.

We trust that this proposal will be acceptable to the Division but will be glad to submit any additional information which may be required.

Very truly yours.

(signed) J. C. MILLER

MANAGER, AVIATION DIVISION

INDUSTRIAL DEPARTMENT

Letter by Major D. J. Keirn, Office Assistant Chief, Materiel Division, War Department Air Corps, Wright Field, Dayton, Ohio, to Chief, Materiel Division, O.C.A.C., Washington, D.C. 31 October 1941.

SUBJECT: Progress Report - Turbo Supercharger Type I.

1. The following covers progress to October 28, 1941:

a. Test house and chimney approximately complete.

b. Engine mount approximately complete but not yet installed in test house.

c. W1X should be installed and ready to run November 2, 1941.

d. Conference between Bell representatives, General Electric engineers and Materiel Division representatives held at Lynn October 27, at which time location of engine accessories and rear mount position were determined.

e. Desirability of wind tunnel test with full scale nacelle to determine characteristics or proposed ducts was discussed. Further discussion postponed until November 4.

f. Some of the General Electric production drawings are ready for release to their shops. Drawings of major parts scheduled for completion approximately November 15.

g. A study of a redesign of the diffuser section in in progress. This is deemed desirable because of the surging difficulties experienced in England.

h. Additional personnel for planning and expediting production have been assigned to the project.

D. J. KEIRN, Major, A. C.

Memorandum for Gen. Henry H. Arnold by Major Donald J. Keirn, 3 November 1941.

MEMORANDUM FOR: H. H. Arnold, Major General, U.S.A. Deputy Chief of Staff for Air.

In accordance with instructions contained in Memorandum dated October 15, 1941, the summary report of the Special Committee on jet propulsion had been carefully studied and the following comments are offered:

a. The Westinghouse proposal is similar in general to the Royal Aircraft Establishment internal combustion unit being built by Metropolitan Vickers of Manchester, England. This unit indicates somewhat higher thermal efficiency than the Whittle, but weighs approximately twice as much.

b. The Allis-Chalmers proposal is similar in principle to the Rolls-Royce but differs greatly in construction details, and apparently will weigh much more.

c. The General Electric project has a number of features which may be advantageous, but are hard to evaluate from the limited data.

d. It is believed that the figures in the report for weight of the conventional power plant are optimistic when the weight of propeller, oil system, cooling system, inter-coolers and superchargers necessary to provide proper functioning at 25,000 feet are considered. Some deduction should also be made for cooling drag of the conventional engine, since air ducting losses are taken into account in estimating performance of combustion turbine.

e. In general, all three proposals should result in units of higher thermal efficiency than the Whittle and have an additional advantage of lower frontal area. However, all of the proposed units will probably weigh more than the Whittle. Weight seems to be of major importance when considering power plants for short endurance, high speed, interceptor aircraft, and for that reason, none of the proposals appear to be superior to the Whittle for that type of aircraft. *f*. The weight estimates in the report indicate that the weight of the internal combustion turbine of the types proposed increases as the 1.4 power of the size. If these estimates are correct, it indicates a limit to the practical size of the internal combustion turbine for aircraft use. Weight estimates on engines of the Whittle type and actual weights of the General Electric turbo superchargers indicate that the weight increases as the 1.14 to 1.2 power of the size. This appears to indicate that the practical limit on size may be greater for the Whittle than for axial flow types. Such a conclusion can be verified, however, only by construction and tests of units of the various designs. *g*. It is believed, therefore, that all three proposals should be developed to an extent that will permit an evaluation of their respective merits.

Donald J. Keirn,

Major, Air Corps.

Incl.: NACA letter dated 10/13/41, signed by J. C. Hunsaker, with copy of Summary Report of Special Committee on Jet Propulsion.

ROUTING AND RECORD SHEET, Headquarters Army Air Forces.

I. From General Arnold to General Echols 6 November 1941.

1. Attached hereto is report of committee of which you are a member, together with Keirn's summary and comments.

2. Draw up a program for the development of these three engines to whatever extent is necessary, dovetail it into our long range development program and submit the program, together with your recommendations as Chief, Materiel Division, to me for approval.

3. This development work must of necessity be kept separate from any other projects that may be underway at the present time.

Incl: Memo 11/3 frm Maj.Keirn

Ltr 10/13 frm NACA br

Cy Summary Rept. of Spec.Comm.

on Jet Propulsion.

II. From General Echols to General Arnold, 12 November 1941.

1. This matter has been discussed quite thoroughly both with the N.A.C.A. and with representatives of the Bureau of Aeronautics. All have agreed fairly well that since the Army already has excellent liaison and several active projects for superchargers with General Electric, it would be best for us to take the General Electric project and let the Navy have the Allis-Chalmers project, which is also closely associated with a number of Allis-Chalmers- Navy contracts. We advised both the Committee and the Navy that we would be glad to take the

Westinghouse development or to share it with the Navy. Since the Committee has recommended that the Navy take both the Allis-Chalmers and the Westinghouse projects, it would probably be best for us to work exclusively with General Electric.

In the Materiel Division considerations of the General Electric program it has been felt that the idea they already have plus ideas that are bound to be suggested by the engine they are now working on should be the basis of a very much improved type of engine and that it should be designed and built simultaneously and in parallel with the present project.

It is recommended that a contract be negotiated immediately with General Electric for design and manufacture of what they consider the best possible engine of this type based on all information at their disposal at the present time.

O.P.E

Chief. Mat. Div.

Memorandum for General Arnold by Gen. Oliver P. Echols, Air Corps, Chief, Materiel Division, 13 November 1941.

MEMORANDUM FOR GENERAL ARNOLD:

Subject: Necessity for Conducting Wind Tunnel Tests on the Bell XP-59a and GE (Type I Supercharger) Projects.

1. As we get deeper into the Bell XP-59A and GE Type I Supercharger projects, we find that in order to exploit the fullest possibilities of this engine-airplane combination, it is desirable to retain the engine and duct set-ups openings. For this reason, it is highly desirable that we initiate wind tunnel studies as soon as possible in order to accumulate data regarding pressure distribution at the duct openings and within the engine nacelles under the different attitudes which will be encountered in actual flight.

2. While it had been hoped that any tunnel tests necessary could be accomplished at Wright Field, thus confining knowledge of this project to the fewest number of people possible, nevertheless further study indicates that it will be necessary to go further than the the Wright Field facilities to obtain the information desired. A relatively large scale model in combination with proper tunnel velocities and tunnel equipment is necessary, and a survey of the tunnel facilities discloses that in order to utilize as large a scale model as possible, the 16 ft. high speed tunnel at Moffet Field or the 19 ft. pressure tunnel at Langley Field, offer the best facilities. A determination between these two tunnels cannot be reached however until such time as the problem can be thoroughly reviewed

with the personnel experienced in the operation of the tunnel and interpretation of the data obtained therefrom. For this reason, authority is requested to confer with Dr. George W. Lewis, Director of Aeronautical Research, N.A.C.A., regarding an accelerated test program on this project.

OLIVER P. ECHOLS Brig. General, Air Corps, Chief, Materiel Division.

The letter bore the following hand-written notes:

1. ″Decision is *NO*!

2. ″Note: 11/14/41 General Echols advised that he had discussed this matter with Gen. A, this date, and that Gen. A did not wish to tunnel test at NACA in view of the ′secrecy′ of project. Therefore it will be necessary to proceed without tunnel tests planning or testing for .. attack if first attempt is a ″bust″ Above information transmitted verbally to General Gardner & Chidlaw by Gen. E.

Appendix B. LETTERS BY THREE MANUFACTURERS

B.1 BELL AIRCRAFT CORPORATION

Letter by D. Roy Shoults, Vice President-Engineering, Bell Aircraft Corporation, to the attention of James M. Mead, Chairman of the U.S. Senate Special Committee Investigating the National Defense Program, Washington, D.C., 14 January, 1946. TLS.

Gentlemen,
Your December 29th request addressed to Mr. Lawrence D. Bell requesting information regarding the valued of research and development carried out by the National Advisory Committee for Aeronautics has been referred to Engineering for reply in view of the highly technical aspects of the Questionnaire. The

following comments are numbered serially in correspondence with the paragraphs of the Questionnaire attached to your reference letter:

1. Bell Aircraft Corporation has made numerous requests to the NACA for advice, tests and research assistance on specific problems.

2. Almost without exception, the assistance requested from the NACA was subsequent to September 8th, 1939 on which date a limited emergency was declared by the President, and in accordance with the Mobilization Plan the NACA activities were governed by the Aeronautical Board. In essence, this limited emergency and the full emergency declared on May 27th, 1941 required NACA to devote the major share of its time to specific problems of high immediate importance and, in consequence thereof, all research was limited in scope.

During the war, the work undertaken by NACA in which Bell had the greatest specific interest was in connection with the six series of airplanes which this Corporation developed and built for the Army Air Forces. All requests for NACA action on these were cleared through the Aeronautical Board. The work, in the main, was carried out in the Langley Memorial Laboratory, although in specific instances the Ames Aeronautical Laboratory and the Aircraft Engine Research Laboratory participated in the program.

The magnitude and scope of the work undertaken is indicated in the following summary which indicates the airplane model under construction, the NACA facility involved, the number of reports prepared and the type of data obtained: [This appendix does not include the above-mentioned document because it did not have any relevance for this study.]

On the tests of the XP-83 and XS-1 models, where our records are most complete and memory most accurate, we find that the first preliminary data became available in all cases within the first month after starting the test. The final reports prepared by NACA were sometimes several months in preparation but we, having the preliminary data available, had in all cases utilized this without loss of time.

3. Prewar *basic research* done by the NACA was of *inestimable value to Bell Aircraft* in carrying out the design work on airplanes built *during the war.* Wartime Basic research programs at the NACA took low priority as the inevitable result of the decision to utilize the NACA facilities to the utmost in attacking the problems of greatest immediate consequence. It is important therefore that the basic research programs of the NACA should receive concentrated attention in the early post-war years and, when necessary to free the NACA facilities, that development testing programs should be carried out in other existing facilities.

We have examined a confidential report of the NACA. "A Survey of Fundamental Problems Requiring Research at Langley Memorial and Ames Aeronautical Laboratories", dated November, 1945, and a memorandum prepared by Mr. Smull, Secretary of the Industry Consulting Committee of the NACA which summarizes the planned distribution of effort of the NACA research program in the future, and we believe, in general, that the programs outlined are of both immediate and long term interest and as such should be prosecuted with vigor.

4. The recent formation of the Industry Consulting Committee of the NACA is believed to be a very forward looking step in bringing a closer relationship between the NACA and the aeronautical industry. It is believed, further, that the industry should be represented by direct membership of a few of its technically qualified leaders on the National Advisory Committee for Aeronautics.

The membership of the various technical committees and subcommittees should be critically examined at the termination of the war with a view to appointing to these committees the most capable technical people who will be *actively engaged* in the post-war period in the technical work within the cognizance of each of the committees or sub-committees. As the NACA facilities are committed to a greater extent to pure research programs it will become more and more necessary to maintain a close liaison with the industry components engaged in applying the results of the research and also, correspondingly, most aware of the zones in which our present knowledge is adequate. Without this close cooperation and liaison between groups of working technicians we cannot hope to expend the research effort in the most fruitful fields or to make the most effective use of the results of the research programs when completed.

In conclusion, it is the belief of the Bell Aircraft Corporation that the NACA and its facilities is the most important tool we as a nation have to maintain the technical leadership most essential to air supremacy. The present facilities are excellent but should be expanded, particularly to cope with out present need for information in the field of transonics and supersonics. With facilities available, funds should without question be allocated to permit their most effective utilization year by year in expanding our fund of technical information. Suitable NACA--Government--Industry relationships can be maintained through technical committee and sub-committee action by suitable selection of membership.

Very truly yours

D. Roy Shoults

Vice President-Engineering

Bell Aircraft Corporation

B.2 DOUGLAS AIRCRAFT COMPANY, INC.

Letter by A. E. Raymond, Vice President-Engineering, Douglas Aircraft Company, Inc., to George Meader, Chief Counsel, Mead Committee, United States Senate, Washington, D.C., January 7, 1946. TLS.

Dear Mr. Meader:

In reply to the inquiry contained in your letter of December 29, 1945, about the National Advisory Committee for Aeronautics, I am very happy to supply such information as I can.

During the war, requests for work by the N.A.C.A. have been channeled by us through the military services, and I unfortunately do not have documentary evidence on hand, but I would say that in general such requests have been complied with satisfactorily. We have had good cooperation and results have been obtained with reasonable promptness considering the high pressure under which the N.A.C.A. laboratories were operating.

The present and proposed program of N.A.C.A. research projects had been summarized in a report prepared by N.A.C.A. under date of November, 1945, and submitted thus far only to members of its Industry Advisory Committee. That committee is requesting a sufficient number of additional copies to permit a coordinated set of comments to be prepared by the industry. Until this has been done, I am not in a position to give you an appraisal of the program, for I have not seen this report except briefly through loan of a copy which was sent the above Industry Advisory Committee.

I believe that the mechanism is now taking shape whereby the aeronautical designers who make use of the results of N.A.C.A. research will in the future have a better opportunity to influence the formulation of its research program. This as I indicated in my testimony before your Subcommittee is Seattle, has been one of the desirable changes.

Those who have studied the subject feel that it also would be advantageous if the composition of the main committee of the N.A.C.A. could be modified to include one member whose background, experience, and training has been connected with the design of aircraft, one who has been active in the design of aircraft engines, and one who has been intimately associated with the operation of aircraft.

I think it is also generally felt that the standing committees might be improved by increasing the representation on them from the aircraft industry, being careful at the same time not to enlarge these committees since they are already larger that they should be for most efficient operation.

N.A.C.A. has in general been handicapped by its inability to compete with private industry in the wages which it pays its people, particularly those under civil service. This has resulted in inability to obtain fully qualified personnel and has at the same time resulted in a relatively higher turnover. I am not sure what Congress can do to overcome this, but it is undoubtedly at the root of much of the criticism that has been heard.

In spite of the large sums of money that have been spent during the war for N.A.C.A. facilities, there is need for more expenditures of this kind in the immediate future, particularly in the construction of supersonic tunnels. At the same time it is by no means certain that all of the present facilities which the N.A.C.A. had should be maintained in continuous operation indefinitely. Some of them are becoming obsolescent and it may not be possible to operate some of them on a peace time budget and at the same time cover the new fields that are of first importance.

It is very important in my opinion that the channels of information between the industry and the N.A.C.A. be opened as wide as possible consistent of course with the requirements of military security. To the extent that this can be done, the needs, problems, and view point of the industry will be better known by N.A.C.A. personnel, and the industry will recognize the N.A.C.A.'s problems, be able to assist in solving them, and will obtain needed information at the earliest possible time. I am encouraged by the progress which has already been made in this direction and feel that if continued, it will go far toward increasing the value received by the country from the investment it is making in governmental research.

I trust that the above may be of some value as a supplement to my testimony in Seattle.

Very truly yours,

DOUGLAS AIRCRAFT COMPANY, INC.

A. E. Raymond

Vice President-Engineering

B.3 CONSOLIDATED VULTEE AIRCRAFT CORPORATION

Letter by Albert E. Lombard, Jr., Engineering Consultant, Consolidated Vultee Aircraft Corporation, San Diego, California, to James W. Mead, Chairman Special Committee Investigating the National Defense Program, Washington, D.C., January 16 1946. TLS.

My dear Senator:

Your letter to Mr. Woodhead of December 29, 1945 regarding the National Advisory Committee for Aeronautics has been referred to me for investigation and reply. Attached are our comments and answers to the questionnaire which you forwarded with your letter.

Your questionnaire has not asked for any comments on the value of the N.A.C.A. to Industry. We would like to add a word on this point and emphasize that we feel that the N.A.C.A. is a very important link in the chain of aviation in the United States. We look to the N.A.C.A. as the organization best equipped to explore the horizons of technological science and aeronautics and to supply the underlying principles and technical data which are needed as we move into new fields. The costs of carrying out fundamental research is so great that it can not be financed by the aviation industry of the United States. New wind tunnels and other equipment must be purchased and operated by the Government.

It is in the above spirit that we have answered your questionnaire as frankly as possible. We trust this will supply the information desired by your Committee.

Respectfully submitted,

CONSOLIDATED VULTEE AIRCRAFT CORPORATION

Albert E. Lombard, Jr.

Engineering Consultant

REPLY TO QUESTIONNAIRE ON N.A.C.A. SUBMITTED BY MEAD COMMITTEE

Question 1: Has your company requested the National Advisory Committee for Aeronautics to work on specific research problems?

Answer During the past five years, three Divisions of this Corporation (San Diego, Forth Worth, Vultee Field) have extensively used the facilities of the N.A.C.A. for conducting wind tunnel tests on new models under development. All of these tests have bee carried out at the request of the Army Air Forces, or Bureau of Aeronautics Navy Department.

Question 2: If the answer to No.1 is "yes", specify the problems and the steps that were taken by the National Advisory Committee for Aeronautics, to your knowledge in compliance with your request, furnishing copies of correspondence or other data which, in your opinion, are material to a determination of the manner in which and the speed with which the research on such problems was conducted.

Answer All test programs were carried out with full Army and Navy approval as to scope and date of completion. It is difficult to judge the N.A.C.A.'s degree of responsibility under such conditions. In at least two instances, test programs which we have proposed on Army airplanes have been modified without our concurrence, but apparently with Army approval. We have no correspondence or other evidence to present in regard to this situation. All we can say is that the result has not been entirely satisfactory to us.

On the other side of the picture, we would like to mention an instance in which the N.A.C.A. has taken the initiative in conducting research on flush intake ducts for jet propelled airplanes after the tests on our XP-81 had indicated a need for such research. A good job was done.

Question 3:: The Committee desires your appraisal of the scope of investigation and research conducted by the National Advisory Committee for Aeronautics, specifying in detail the research projects engaged in and appraising their usefulness to the future of aeronautics.

Answer We believe that the N.A.C.A.'s basic research program has been inadequate for the following reasons:

(a) The work required of the N.A.C.A. by the Army and Navy during the war years has been directed largely to improvement of specific models so that basic research has been neglected.

(b) The N.A.C.A.'s research program over the past ten years has not been sufficiently broad and systematic, except in certain field. There has been a tendency to jump around and hit the high spots.

(c) The N.A.C.A.'s basic research program has lagged behind the needs of the aircraft industry in connection with high speed research, airplane diving speeds having been higher than speeds obtainable in available wind tunnels. The XP-81, for example, was tested in the wind tunnel to Mach number = 0.825, while the design diving speed was considerably above this Mach number. It is conceivable that this lack of wind tunnel facilities sufficiently advanced of airplane flight speeds has been due to lack of funds for their construction and operation. In addition, we feel that it has been due to lack of sufficient vision in advance planning by the N.A.C.A. to properly anticipate the progress of aviation. The N.A.C.A. has recently taken steps to work more closely with the aircraft industry in establishing and conducting its research programs. It is too early to evaluate the effectiveness of this section.

Question 4: Comment upon the administrative structure and personnel of the National Advisory Committee for Aeronautics and the general of its activities in aircraft research and development, specifying in detail the advantages or shortcomings of the National Advisory Committee for Aeronautics as they have come to your attention, offering any suggestions you may care to, either as to the modification of the administrative structure or staff or operations of the National Advisory Committee for Aeronautics, or any suggestions you may care to make as to other government-sponsored research and development activities, which, in your opinion, should contribute to the most desirable development of aircraft in the future for the United States.

Answer The administrative structure of the N.A.C.A. can be improved by greater participation by the aircraft industry in the future planning of the work of the N.A.C.A. in order for this work to have maximum effectiveness in the shortest period of time. This should include a better representation of the aircraft industry on the main committee of the N.A.C.A. as well as its working committees and subcommittees. It should also include a broader distribution to the aircraft industry on the research programs contemplated and in progress so that the industry's appraisal of the urgency of the individual items may be had.

With respect to the detail operations, we wish to offer the following comments:

(a) As discussed under Question 2, manufacturers' programs have been modified by the N.A.C.A. apparently with Army approval but without manufacturers' approval.

(b) Test data obtained on manufacturers' models have not been made available to engineering representatives as they were obtained, but only after a complete preliminary report has been written.

(c) The N.A.C.A. has held conferences regarding manufacturers' tests but manufacturers' representatives have not been invited to the conferences.

(d) Library and N.A.C.A. reports have not been made available to manufacturers' representatives at the laboratories during progress of tests.

The vita has been removed from the scanned document