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A HISTORY OF THE LANGLEY RESEARCH CENTER,
1917-1947

by

Michael David Keller

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I hereby recommend that this dissertation prepared under my direction by Michael David Keller entitled A History of the Langley Research Center, 1917-1947 be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy.

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Michael D. Keller
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ABSTRACT

At the opening of World War I, the United States had no organization to coordinate and conduct scientific research in fundamental aerodynamics. In 1915, the Congress authorized appointment of a National Advisory Committee for Aeronautics to overcome this deficiency. Within two years the NACA completed plans for a research laboratory to be constructed near Hampton, Virginia.

Named the Langley Laboratory, after pioneer aerodynamicist Samuel P. Langley, the NACA research station remained the only United States center for fundamental aerodynamic research for more than two decades. When the NACA required additional research stations, Langley personnel planned and staffed the new laboratories. Virtually every airplane flying shows some results of Langley investigations.

Laboratory engineers conducted tests leading to innovations in air-cooled engine cowlings, airfoil shapes, engine placement, landing gears, structures, and aircraft instrumentation. They collected and published reports on almost every area of aeronautical technology.

Langley personnel also expended much effort in the development of more sophisticated research tools to
be used by aeronautical engineers. The instrumentation division of the laboratory invented many devices to record the forces on an airplane in flight. Most important among the research devices originated at Langley were improvements in the art of wind tunnel technology. Developments included, among others, a wind tunnel unaffected by the scaled-down size of an airplane model, a tunnel for the investigation of spinning problems and one of a large enough size to allow testing of a full size airplane. Wind tunnel innovations increased the safety of testing; radical design changes could be investigated without endangering the life of a test pilot.

During the Second World War, fundamental research at Langley was reduced while laboratory engineers carried out a series of "clean-up" tests on military aircraft. Slight design changes increased the maximum velocity and overall efficiency of the airplanes employed by the armed services. These improvements increased the scope of aerial tactics and were of tremendous value to the United States war effort. Practical value of the efforts of the Langley Laboratory were most evident during the wartime period.

Near the end of World War II, the laboratory began a joint venture with the Army Air Service and the Navy to develop an airplane entirely for research
activities. The project had a dual purpose: acquisition of flight data in the mysterious transonic speed range; and an attempt to break the sonic barrier. Following construction of the airplane by the Bell Aircraft Corporation, the X-1, on October 14, 1947, became the first aircraft to achieve level flight faster than the speed of sound. The third decade of Langley activities closed on this successful note.

At the base of the success of the Langley Laboratory lies the concept of cooperation. The staff at the laboratory worked very well together and their cordial relations with the Washington office of the NACA provided mutual benefits. In addition to the internal harmony, the NACA and its laboratory enjoyed the close cooperation of the armed services and the American aviation industry. Naturally the agreeable spirit which existed did not come about by accident; it resulted from the efforts of numerous individuals interested in the advancement of American aviation. These efforts led to the Langley Laboratory becoming an outstanding example of successful governmental sponsorship of scientific research.
CHAPTER I

EARLY RESEARCH IN AERONAUTICS

Almost from the beginnings of recorded history, man has displayed a desire to escape the boundaries of the earth and to fly with the alacrity of the birds he saw gliding around him. Although many centuries were to pass before he escaped the earth's gravitational pull, man dreamed of this day in some of his earliest myths.

One of the most notable Greek myths is that of Daedalus and Icarus originating about the twelfth century B.C. According to this myth, Daedalus, while imprisoned in a tower, fashioned a pair of wings using thread and wax to join them together. Icarus, his son, was given a pair of these wings but told not to fly near the sun which, of course, he did despite the warning. The heat from the sun melted the wax causing the wings to melt and Icarus was drowned after plunging into the sea. Perhaps a warning to obey one's parents, this myth is one of the earliest acknowledgments of a desire to fly.

Most illustrious of the Medieval scientists devoted to conquering flight was Leonardo da Vinci.

(1452-1519), genius of the Italian Renaissance. Although he concentrated on the development of an ornithopter (flapping wing device propelled by human power), da Vinci is generally credited with drawing the oldest plans for a helicopter and a parachute. The results of Leonardo's investigations remained unknown for almost a hundred years and, therefore did not serve as they might have, to spur others in research in aerodynamics.  


Shortly after the flight of the Montgolfier brothers, Professor Charles of the Paris Academy rose in a hydrogen balloon thirteen feet in diameter to the delight of his spectators including Benjamin Franklin. This flight lasted some two hours and covered a distance of twenty-seven miles but, in his next trial, with a rubberized fabric hydrogen balloon, Professor Charles rose rapidly to 9,000 feet, became frightened by the altitude, and subsequently decided never again to attempt flight.

Ballooning soon became a popular sport and Pitatre de Rozier became the first aerial casualty in an attempt to cross the English Channel in 1785. George Washington witnessed the first American balloon flight at Philadelphia in 1793. Experiments continued throughout the first half of the nineteenth century with a view toward complete controllability of the balloon. As early as 1785, the Frenchman Vallet attempted to install an airscrew [propeller] on a balloon, but not until 1884 was the first electrically-driven airscrew developed.


5. Gibbs-Smith, Ballooning, 18.

6. Ibid., 18-23.
Balloon flight, however, could not satisfy man's desire to find the secret of heavier-than-air powered flight. Gliding and model airplane building became the next step in the evolution of flight. Of limited note were the experiments of an Englishman, John Stringfellow, who designed a model in 1848 which flew the enormous distance of 120 feet! Actually, at this time the Stringfellow accomplishment was significant and fore-shadowed the development of a practical flying machine.  

Foremost among the European aerodynamicists in the nineteenth century was the Frenchman, Alphonse Pénéaud. His models pointed out the need for inherent stability in aircraft and his "twisted rubber" engines predated what later became the "power plant" for children's models. Pénéaud's researches were followed shortly by Otto Lilienthal, a German who made a thorough study of bird flight. Lilienthal's work with gliders is considered to have led directly to the success of the Wright brothers, who enthusiastically studied his findings.  


8. Ibid., 15-25; Lankes, "A Brief History of Aeronautics," 9. Also important in the evolution of aeronautics toward powered flight was the increased development of steam and gasoline engines. See C. H. Gibbs-Smith, The Aeroplane (London: Her Majesty's
Among the earliest Americans interested in the achievement of flight was Octave Chanute who had previously gained considerable fame as a construction engineer. His primary concern, in his glider research, was the problem of inherent stability of an aircraft. Later Chanute became closely associated with the work of the Wright brothers. As liaison for the Wrights, Chanute traveled to Europe in 1903 as the so-called American "ambassador of aviation." 9

Certainly the most widely known American aerodynamicist, prior to the Wrights, was Dr. Samuel Pierpont Langley who had originally won renown for his work in astrophysics. Langley first became interested in the study of aerodynamics while serving as director of the Allegheny Observatory in 1886. With funds contributed by Pittsburgh millionaire William Thaw, he built a turning wheel on which he tested airfoil sections at various angles to study their air resistance. Shortly


thereafter he moved to Washington to become Secretary of
the Smithsonian Institution.10

At the Smithsonian, Langley continued his
aerodynamic studies. He read the works of Alphonse
Pénaud and is said to have been greatly influenced by
them. Langley's earliest models, constructed in 1893,
were partially patterned after the Pénaud example of the
twisted rubber "power plant." Soon he placed a small
steam engine on his "aerodrome" models. On November 18,
1893, Langley attempted to fly a model weighing about
ten pounds at Widewater, Virginia, located thirty miles
down the Potomac River from Washington. Though this
model failed because of a lack of stability, Langley's
Aerodrome No. 5 flew approximately 3,000 feet in one
and one-half minutes on May 6, 1896.11

Langley's successes impressed the Assistant
Secretary of the Navy, Theodore Roosevelt, who wrote
to his superior, Secretary John D. Long, suggesting that
the government financially support Langley in an attempt

10. John Hettich, "Langley Goes Down to the
River," Aero Digest, 52 (February, 1946), 38. Interview
with Paul E. Garber, August 30, 1966.

Remarks prepared on the occasion of his presentation of
a bust of Dr. Langley to the Langley Research Center,
May 24, 1961, 5. Hettich, Aero Digest, 52 (February,
1946), 161.
to build an airplane "on a large enough scale to be of use in the event of war [with Spain]." Partly as a result of Roosevelt's suggestions, Langley secured two $25,000 grants from the Board of Ordnance and Fortifications of the War Department to finance investigations leading to the construction of a full-sized, man-carrying airplane.

With these funds, Langley began to construct a full-sized airplane which he hoped to launch from a refitted houseboat on the Potomac. Langley was assisted in the development of a power plant by Charles M. Manly, who designed an engine based on the earlier ideas of a New Yorker, Stephen M. Balzer. Manly was also the pilot during the two attempts made to fly the Langley machine, October 7 and December 8, 1903. Both attempts were failures but Manly escaped unhurt. The public, however, was quite aware of Langley's trials and he was severely criticized for having "squandered" $50,000 of


Langley lived only until 1906 and never again attempted to fly—he is often said to have "died of a broken heart" because of this failure. One aviation historian has appraised Langley's work: "although his models were successful in their limited sphere, his influence on the technical progress of aviation was slight." Only nine days after the final failure of Samuel P. Langley's airplane, the Wright brothers, in relative obscurity, achieved the first heavier-than-air, controlled power flight at Kitty Hawk, North Carolina. The Wrights had become interested in flight in 1896, and began active experimentation in 1899, after Wilbur wrote to the Smithsonian asking for a bibliography of publications on aviation. Both brothers read all the available

16. Ibid. Interview with Paul E. Garber. In May, 1914, because of a patent suit, Glenn L. Curtiss reconstructed the Langley aerodrome and flew it at Hammondsport, New York, with considerable design changes from the original Langley machine. This set off a dispute between Orville Wright and the Smithsonian Institution which lasted to 1942. Dayton, Ohio Journal, May 29, 1914; Gibbs-Smith, The Aeroplane, 222; Wright Papers, II, 1092-1098
18. Wilbur Wright to Smithsonian Institution, May 30, 1899, Wright Papers, I, 4-5.
works and then began building models and gliders.

In May, 1900, Wilbur wrote to Octave Chanute\textsuperscript{19} outlining his ideas on flight and thus began one of the most fruitful series of correspondence in the history of American scientific development.\textsuperscript{20} In 1901, the Wrights built a small wind tunnel in their Dayton, Ohio, workshop.\textsuperscript{21} As a location for their gliding and later flight experiments, the Wrights selected Kitty Hawk, North Carolina. Information received from the Weather Bureau concerning prevailing winds in the area, influenced their decision.\textsuperscript{22}

In September, 1900, they established a camp at Kill Devil Hill at Kitty Hawk, and kite and gliding experimentation began. After numerous experiments and revisions of some of their earlier ideas, the Wrights

\begin{itemize}
\item \textsuperscript{19} Wilbur Wright to Octave Chanute, May 13, 1900, \textit{Wright Papers}, I, 15-19.
\item \textsuperscript{20} Much of the correspondence between Chanute and the Wrights, and many items concerning Chanute alone is in the \textit{Wright Papers}, I, II, \textit{passim}.
\item \textsuperscript{21} The first complete wind tunnel laboratory was also erected in 1901 under the supervision of Dr. A. F. Zahm at the Catholic University of America in Washington, D. C. N. H. Randers-Pehrson, "Pioneer Wind Tunnels," \textit{Smithsonian Miscellaneous Collections}, Vol. 93, No. 4, January 19, 1935.
\item \textsuperscript{22} \textit{Wright Papers}, I, 23n.
\end{itemize}
made their first attempt at powered flight on December 14, 1903. Minor errors prevented success, but three days later, on December 17, the Wrights successfully completed four flights, the first, with Orville as pilot, (having won a coin toss) of 120 feet in 12 seconds, and the longest a flight of 852 feet in 59 seconds. For the first time man had achieved powered heavier-than-air, controlled flight!

Those interested in aviation today look back to December 17, 1903, with great reverence as a day in which the course of human history was significantly altered; those living in late 1903, however, either did not know of the flights or, if they heard reports of the successes of the Wrights, refused to believe them. In May, 1904, the press was invited to view a test of Wright Flyer No. 2 near Dayton, Ohio, but, when the brothers were unsuccessful in the first two days of trials, the press left convinced that the claims of the Wright brothers were fraudulent.

As late as January, 1906, Scientific American, one of the leading scientific journals of the day, 

23. Ibid., 394-97.

remarked in response to reports of the Wright's achievements in September of 1905 that "we have the right to exact further information before we place reliance on these...reports....If such sensational and...important experiments are being conducted...is it possible that the...American reporter...would not have ascertained all about them?"25 One reason for this general lack of information was the secretive nature of the Wrights themselves; they hoped by keeping their experiments secret to protect their patent rights.26 Finally, in December, 1906, Scientific American acknowledged the accomplishments of the Wrights editorially, saying, "In all the history of invention there is probably no parallel to the unostentatious manner in which the Wright brothers...ushered into the world their epoch-making invention of the first successful aeroplane flying machine."27

Another possible cause for this want of detailed information was the general press reaction to the flights


of December, 1903. The press was, at best, quite skeptical. The flights, coming so soon on the heels of the Langley disaster, prompted newspapermen to discount stories of the Wrights' success. Only two days after the flights, one newspaper carried a front-page story citing a report originating in Norfolk, Virginia, that the Wrights had flown. This statement, however, was almost the only accurate feature of the account, which described the Wright plane as having "two six-bladed propellers, one below the center of the frame...exerting upward force...the other at the rear furnishing forward impetus." In consequence of the Wright's own reluctance, and disbelief by the news media, the general public waited literally years before receiving an accurate account of the first flight.

From late 1904 until almost the end of 1906, the Wrights attempted to make their machine available to the United States government through the Army Board of Ordnance and Fortifications. Only the apparent stupidity of the Board caused Wilbur and Orville finally to be frustrated in this effort. They then took the obvious step--they offered the Wright flyer for sale to interested

European governments. Thus, despite the fact that the first successful aircraft was an American invention, European governments were first in taking an active interest in its military possibilities.29

The Signal Corps of the United States Army, finally interested in aviation, released its first specification for an airplane on December 23, 1907. Among the specifications outlined by the Signal Corps were included requirements that the airplane: (1) must be designed so that it could be assembled and operated within about one hour; (2) must carry two people, combined weight of 350 pounds, and sufficient fuel for a flight of 125 miles; (3) must have a speed of at least 40 miles per hour in still air; (4) must have a trial over a five-mile course, flying with and against the wind; (5) must have a trial endurance flight of one hour during which it will be steered in all directions; (6) must land without a specific field designed for that purpose; (7) must have some device for safe descent in case of accident to the propelling machinery; (8) must be relatively easy to operate; and (9) must

29. This fascinating story is recounted in Kelly, The Wright Brothers, 147-165.
include with the purchase price the training of two men to operate the machine.  

On February 10, 1908, the Signal Corps signed a contract with the Wright brothers for "one heavier-than-air flying machine," within the terms of the previously stated specifications. Delivery was scheduled to be made on or before August 28, 1908, at a cost of $25,000.  

The first airplane was delivered to the Army on July 30, 1909, at Fort Meyer, Virginia. Because the plane flew at 42.5 miles per hour during the tests, the Wrights were awarded a $5,000 bonus above the original contract price. The designation given the craft was "Aeroplane No. 1, Heavier-than-air Division, United States Aerial Fleet." The first two pilots trained by the Wrights were soon transferred to other assignments and Lieutenant Benjamin D. Foulois, having taken flight instruction by correspondence (!) from the Wrights, became the first Army officer given orders for regular flying duty. With this rather inauspicious start, the Army began its use of aviation for military purposes.  

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32. ATC Pamphlet 190-1, p. 5.
By 1910, other aerodynamicists had begun extensive research to improve what the Wrights had originated. As early as 1907, Blériot built a full-sized airplane with cantilevered wings. In America, Glenn L. Curtiss in 1911 introduced his "Flying Fish," the world's first successful hydroplane. Other developments in aeronautics included the opening of the first airline with scheduled flights in 1914; the establishment of a small aeronautical laboratory by the Navy at the Washington Navy Yard; and the institution, in 1913, of the first course of instruction in aeronautics at the Massachusetts Institute of Technology.

Although a 1913 report told of developments in aeronautical research in Europe, very little activity in organizing research occurred in the United States.

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34. Gibbs-Smith, The Aeroplane, 87. Ruth Walred, "Origins (of NACA)," unpublished manuscript, NHA, 7. The original course in aeronautics was taught by Jerome C. Hunsaker, later Chairman of the NACA, Walter T. Bonney, unpublished manuscript, with notation "For Smithsonian, 7/18/55," NHA.

35. These reports resulted from a Smithsonian-sponsored trip to Europe by Dr. A. F. Zahm and J. C. Hunsaker. Hunsaker's reports are in "Biography File," Box 12, Record Group 255, National Archives.
One observer noted that the Curtiss Aeroplane and Motor Corporation "had by great development efforts become equivalent to one-half of the whole airplane industry in America," but was conducting very little organized research. 36 It was further alleged that by the time the war in Europe erupted, only about a dozen men in America were knowledgeable enough to design training planes for the Army. The weakness of America's efforts in aeronautics was evident by the time this country entered the war in 1917. 37

With this background, it was obvious that the federal government would have to take some action to stimulate aeronautical research in the United States; indeed many plans for federal activity had been postulated. The drive for federally-sponsored research needed an unbending leader--this leadership was provided by Dr. Charles D. Walcott, successor in 1906 to Dr. Langley as Secretary of the Smithsonian Institution.


CHAPTER II

ESTABLISHMENT OF THE NACA, 1910-1915

In the establishment of the National Advisory Committee for Aeronautics, Dr. Charles Doolittle Walcott played by far the most prominent role. Despite his training as a geologist, Walcott was unfalteringly dedicated to governmental-sponsored research in aeronautics. His aeronautical interest resulted from his enthusiasm for all scientific activity, although his empirical research centered on geology. From the date of his appointment as Secretary of the Smithsonian Institution in 1906, following the death of Dr. Samuel P. Langley, Walcott sought support from the federal government for extensive research in aerodynamics. He was determined that the aeronautical investigations Langley had begun in the latter half of the nineteenth century would not be in vain.

Closely associated with Walcott in this fight was Dr. Alexander Graham Bell, member of the Smithsonian Board of Regents and a man of considerable reputation in the scientific community. He and Walcott also were members of the National Academy of Sciences, an organization originally established during the Civil War. Bell and Walcott undoubtedly led many Academy members, who
were the most prominent American scientists, to understand
the necessity for federally sponsored research in
aerodynamics. 1

From the time of the Wright brothers' flights in
December, 1903, almost to the outbreak of World War I,
governmental interest in aviation in the United States
lagged behind the programs of European governments. With
the exception of a few Army officers concerned with the
military applications of flight, the United States
government abstained from any active role in aeronautical
development. 2

Americans, in general, were more concerned with
domestic policy. The airplane was presumed to be
useful only in the military implementation of foreign
policy. Isolationist feeling was quite intense and
few people envisioned any great value to be gained by
aeronautical development in the United States. The
knowledge that European governments were outstripping

1. Jerome C. Hunsaker, "Forty Years of
Aeronautical Research," Annual Report of the Smithsonian
Institution, 1955, 243-44.

2. At the outbreak of World War I, for example,
the estimated airplane strength was: France, 1,400
airplanes; Germany, 1,000; Russia, 800; Great Britain,
400; and the United States 23. See U. S. House, Letter
from the Board of Regents of the Smithsonian Institution
Transmitting a Memorial on the Need of a National
Advisory Committee for Aeronautics in the United States,
the United States in aviation progress, was of little interest to the majority of Americans in the early years of the twentieth century.

Despite this public apathy, Charles D. Walcott continued to promote interest in the development of American aeronautical activity. In 1910, the first plans were formulated for an advisory committee on aeronautics. At the request of Walcott, Bell conferred with Dr. Albert F. Zahm and Major George O. Squier of the Army Signal Corps "in relation to conducting such experiments on the physics of the air, as will be of service in the development of aerodynamics."  

Letters from Zahm and Squier to Bell reveal much of the concept of what later became the National Advisory Committee for Aeronautics. Zahm suggested that the Smithsonian should invite "a few persons interested in that science [aerodynamics] to form an advisory committee to co-operate in a suitable way toward establishing an aerodynamic laboratory at the National Capital."  

3. Dr. Zahm was familiar with the experiments of S. P. Langley and was quite well versed in the basic techniques of aerodynamics.


5. A. F. Zahm to A. G. Bell, May 1, 1910, Secretary's File, 1909-1924, SIA.
Major Squier's recommendations were quite similar. He proposed a committee to include "a representative of the army, the navy, the department of Commerce and Labor (Bureau of Standards), and the Weather Bureau, and such other members as seem desirable to give the committee the highest scientific standing." 6

Bell, agreeing with Zahm and Squier, felt that appointment of an advisory committee by "either the Smithsonian Institution, or by the President of the United States, seems to me to be the first step to be undertaken." He thought it might be necessary to request a small appropriation from Congress to carry out laboratory experiments. The success of the newly formed British Advisory Committee for Aeronautics was also noted by Bell, who stated that "Lord Rayleigh's admirable report [to Parliament] might well be taken as a basis for work in the United States." 7 With these suggestions, Walcott had a proposal to take before the President.

6. G. O. Squier to A. G. Bell, May 1, 1910, Secretary's File, 1909-1924, SIA.

7. A. G. Bell to C. D. Walcott, May 2, 1910, Secretary's File, 1909-1924, SIA.
Dr. Walcott's efforts resulted in the appointment of a nineteen-man commission, named on December 19, 1912, by President William Howard Taft. This commission became, however, merely the first in a long series of efforts to establish a national research laboratory in aeronautics. The action leading to its creation was most directly precipitated by the recommendation of the Navy Department and Navy Secretary G. von L. Meyer, in a letter to the President on December 16, 1912. The commission was to "consider for recommendation to

8. It is interesting to note how many of the same names appeared on the various aeronautical committees and commissions, and later on the roll of the National Advisory Committee for Aeronautics. The commission appointed by Taft included Dr. R. S. Woodward, president of the Carnegie Institution of Washington; Charles D. Walcott of the Smithsonian; Dr. S. W. Stratton, Director, U. S. Bureau of Standards; Professor W. J. Humphreys, consulting physicist, U. S. Weather Bureau; Brig. Gen. James Allen, U. S. A., Chief Signal Officer; Major Samuel Reber, Chief Signal Officer, Eastern District; Captain W. I. Chambers, U. S. N., in charge of Naval aviation; Naval Constructor David W. Taylor, U. S. N., in charge of the naval model basin; Mr. M. B. Sellers, technical committee, Aeronautical Society, New York; Henry A. Wise Wood, scientific engineer, Aero Club, Chicago; Professor W. F. Durand, scientific engineer, Stanford University; Professor Richard MacLaurens, president, Massachusetts Institute of Technology; Charles M. Manly, New York, formerly with Dr. Langley; Harold H. Sewall, Bath, Maine; Hon. Herbert Parsons, New York; Col. Frederick H. Smith, Peoria, Illinois; Hon. F. W. Rollins, New Hampshire; and Dr. A. F. Zahm, secretary, Aero Club of Washington.


Congress, the necessity or desirability of the establishment of a national aerodynamical laboratory, its organization, most suitable location, and the cost of its installation."\textsuperscript{10}

The commission, after three meetings under the chairmanship of Dr. Robert S. Woodward of the National Academy of Sciences and the Carnegie Institution of Washington, recommended the establishment of a national aeronautical laboratory. The commission further recommended that the direction of this laboratory come from the Smithsonian Board of Regents, with a thirteen-man committee to formulate policy. The Taft commission estimated that the first year operations would cost approximately $50,000. The laboratory should be built in Washington "conveniently accessible to statesmen of the National Government who may wish to witness aeroplane demonstrations."\textsuperscript{11}

A procedural error, however, prevented any action on the commission's recommendations. President Taft had appointed the commission without the necessary


\textsuperscript{11} Hunsaker, \textit{Annual Report of the Smithsonian Institution}, 1955, 244; Walter T. Bonney, Unpublished manuscript, with notation "For Smithsonian, 7/18/55," National Aeronautics and Space Administration Historical Archives (NHA).
"advise and consent" of the Senate. An attempt to pass legislation authorizing the implementation of the commission's recommendations failed to gain a majority and the report was shelved. The $591.66 expenses the commission incurred were never appropriated.  

Despite this setback, Walcott refused to abandon his plan to establish an aerodynamics laboratory to carry on his predecessor's investigations. In May, 1913, he presented to the Board of Regents of the Smithsonian Institution a plan to reopen the Langley Laboratory and to secure an advisory committee to direct the work of this laboratory. The laboratory was to be expanded, providing a "large and a small wind tunnel, ampler shops, and instrument and model rooms." The headquarters of the committee would be "adjacent to this [laboratory], with the collections of aeronautic publications and exhibits, and with designing rooms where plans for


13. By statute the Smithsonian Board of Regents included three Senators and three members of the House of Representatives.

14. This was the laboratory, on the grounds of the Smithsonian Institution, at which Dr. S. P. Langley had carried out many of his earlier experiments with flight techniques.
aircraft may be matured by fabricators in consultation with the technical staff." The report, published by the Smithsonian Regents, observed that "a suitable site is the public land in Potomac Park in the vicinity of the Smithsonian Institution." Because no government funds were readily available, the Regents declared that the operation of the laboratory and proposed committee "will have to be sustained largely by private resources." Walcott tried to obtain funds from a private foundation to construct a building in which to house an aerodynamic laboratory. He wrote Mrs. Russell Sage in 1914 and suggested the "establishment in Washington of a Russell Sage Laboratory for Aeronautics to promote the safety and practical usefulness of aircraft." He estimated the cost of the building to be $100,000, but Mrs. Sage showed little enthusiasm for the project. Walcott then wrote to Andrew Carnegie asking $100,000 to build a laboratory. Carnegie refused


17. C. D. Walcott to Mrs. Russell Sage, March 31, 1914, Secretary's File, 1909-1924, SIA; E. L. Todd, secretary to Mrs. Sage, to Walcott, April 1, 1914, Advisory Committee on the Langley Aerodynamical Laboratory Papers, SIA.
saying he "would not be happy helping the development of the aeroplane for war purposes....When Nations prohibit aeroplanes in war, it will be time enough for philanthropists [sic] to help develop the art of flying."18

When Walcott proved unable to secure private funds, the Regents authorized his plan to obtain the approval of President Woodrow Wilson for the reopening of the laboratory and for the appointment of representatives from the Departments of War, Navy, Agriculture, and Commerce to serve on the advisory committee.19 Wilson responded that he took "pleasure in...expressing my full approval of the designation of representatives of those Departments upon the committee which you are forming for the study of the subjects of aeronautics." On May 9, 1913, the departmental representatives, along with a number of private individuals, were named to the committee.20

18. C. D. Walcott to Andrew Carnegie, May 13, 1914, and Carnegie to Walcott, May 15, 1914, Advisory Committee for the Langley Aerodynamical Laboratory Papers, SIA.


20. Woodrow Wilson to C. D. Walcott, May 9, 1913, in "Minutes of the Advisory Committee on the Langley Aerodynamical Laboratory for May 23, 1913," Secretary's File, 1909-1924, SIA. For a personal
On May 23, 1913, the advisory committee held its first meeting in one of the offices of the Smithsonian. The members decided that the headquarters of the committee should be in the Smithsonian and that the Langley Aerodynamical Laboratory might be financed by federal funds "not to exceed ten thousand dollars the first year, and five thousand annually for five years."

It was hoped further that the War and Navy Departments would assign aviators and airplanes to aid the committee in carrying out their experiments. The committee which supervised the laboratory was to "plan for such theoretical and experimental investigations, tests and reports, as may serve to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, national defense, and the welfare of man." No money would be used to promote inventions or to train aviators

recounting of these moves, see the testimony of Charles D. Walcott in U. S. House, Naval Affairs Committee, Hearings on Estimates Submitted by the Secretary of the Navy, 1915, 63d Cong., 3d Sess., 1915, 1220. (Hereafter cited as U. S. House, Naval Affairs Committee, Hearings.) Members of the Committee were: Brig. Gen. G. P. Scriven, U. S. A.; Major Edgar Russel, U. S. A.; Captain W. I. Chambers, U. S. N.; Naval Constructor H. C. Richardson, U. S. N.; Dr. W. J. Humphreys; Dr. S. W. Stratton; Dr. A. F. Zahm; Orville Wright; Glenn H. Curtiss; John H. Hammond; and Dr. C. D. Walcott. Washington Post, May 24, 1913.
or engineers, and any work undertaken for private concerns would be financed by the requesting firm. 21

At this point Walcott felt that he finally was on the verge of accomplishing what he had tried so hard to do—re-establish the laboratory of Samuel P. Langley and bring the Smithsonian to the forefront of aeronautical research in the United States; but, unfortunately, a procedural problem arose again. Although the committee members were to serve without compensation, Walcott was advised that an Act of 1909 [Sec. 9, 35 Stat., 1027] might prove to be an obstacle. He wrote the Comptroller of the Treasury requesting a ruling which would decide if the statute would prevent the Smithsonian Institution "from requesting the heads of departments to permit members of their respective departments to meet at the Institution and serve on an advisory committee." 22

George E. Downey, Comptroller of the Treasury, answered that since no committee to "investigate or make tests in regard to aeronautical machines and appliances (had) been created by law...detail by heads of Departments of employees...to serve on an advisory committee...would


22. C. D. Walcott to G. E. Downey, March 16, 1914, Secretary's File, 1909-1924, SIA.
come within the prohibition" of the 1909 law.23 Therefore, without a committee to advise it, the Langley Aerodynamical Laboratory, which had reopened under the direction of Dr. Albert F. Zahm, was again closed.24 Possibly because of the earlier failure no attempt was made at this time to acquire Congressional authorization for the recommendations of the committee. After a few informal meetings, the committee was disbanded.25

It was obvious by now that the establishment of a research laboratory would be unsuccessful until Congressional authorization was obtained. A slight change in the attitude of Congress was evident in July of 1914 when that body authorized the Army Signal Corps to create an aviation section. The Signal Corps was given responsibility for the "operation or supervision of operation of all military aircraft, all pertinent appliances, signaling apparatus when installed on air

23. G. E. Downey to C. D. Walcott, March 17, 1914, Secretary's File, 1909-1924, SIA.


25. Bonney, Heritage of Kitty Hawk, 159; Lee Pearson, "The Aerodynamic Laboratory," Unpublished manuscript, NHA.
craft and training in aeronautics."  

Certainly, even this minor evidence of federal interest in aeronautics must have heartened Walcott and others calling for national coordination of aeronautical research.

The advocates of a governmental research organization pointed to aeronautical developments in Europe and urged that America should not fall behind. The French, who had taken an almost immediate interest in manned flight following the 1903 successes of the Wright brothers, had been among the first to establish an aerodynamical laboratory at Chalais. An advisory committee directed research in the French laboratories. The most prominent Frenchmen, both civilian and military, with an interest and knowledge of aeronautical science served on the committee. Furthermore, the contributions to aerodynamics of Gustave Eiffel, based on research at his laboratory at Auteuil, were well-known throughout the world.  

Russia, Germany, and Italy also established laboratories in order to conduct aeronautical research. Coordinated with the University of Moscow, and under the direction of Dr. Dimitri P. Riabouchinski, the


Russian laboratory at Koutchino was said to have been provided with an annual income of $18,000 since its inception in 1904. Private and governmental funds were provided for the German laboratory at the University of Göttingen under Professor Ludwig Prandtl. The Italian Specialist Brigade of Engineers kept that country's researches under military control. Many early investigations at the Italian laboratory were directed toward the "production of the eminently efficient models of Italian dirigibles." 28

In April, 1909, the British created an advisory committee for aeronautics. This thirteen-man committee, appointed by the Prime Minister with Lord Rayleigh as president, established a branch on aerodynamics in the National Physical Laboratory of England. In addition, the committee provided direction for aeronautical research at the Royal Air Craft Factory and at the British Meteorological Office. Funds for research were granted directly by the British government and most of the research was therefore directed toward military ends. Some investigations, however, were performed for private individuals who were assessed "suitable fees, but without

28. Ibid., 8.
guaranteeing secrecy as to the results." Knowledge of the British plan for governmental research in aerodynamics played an important role in the design of an advisory committee suitable to conditions in the United States.

Congressional activity began with a United States House of Representatives Report in 1913 which observed that an American laboratory might be partially financed by private individuals. It declared that:

It is understood that there are a number of wealthy patriots ready to contribute large endowments to such an institution in this country provided the Government will first place the stamp of its approval and encouragement by establishing a national laboratory broad enough in scope to coordinate all the efforts of our various Government departments, our numerous manufacturing plants, and all of the various civil institutions of learning and endeavor that may be able to cooperate in building up a national prestige in aeronautics worth having.  

29. Ibid.; Also see A. F. Zahm, "Report on European Aeronautical Laboratories," Smithsonian Miscellaneous Collections, Vol. 62, No. 3 (July 27, 1914), 1-2. Dr. Zahm, along with Jerome C. Hunsaker, Assistant Naval Constructor, U. S. N., visited the London, Paris, and Göttingen aeronautical laboratories in August and September, 1913, at the behest of the Smithsonian Institution. They took notes on everything they saw which helped lay the foundation for the Smithsonian proposal to Congress advocating governmental establishment of an aeronautical research coordinating committee. On this trip, also see Hunsaker, Annual Report of the Smithsonian Institution, 1915, 244-45.

With this encouragement, Walcott and his associates on the Board of Regents of the Smithsonian Institution undertook a concerted effort to gain Congressional approval of their plan for government-sponsored aeronautical research.

Before a formal request to Congress could be made, it was necessary to organize a committee from the Smithsonian Regents to draft a proposal and formulate strategy for its passage. For this reason, Dr. Alexander Graham Bell, at the December 10, 1914, annual meeting of the Smithsonian Board of Regents introduced a resolution "...that a committee be appointed by the Chancellor, to consist of four members of the Board and the Secretary, to consider questions relative to the Langley Aerodynamical Laboratory." Upon passage of this resolution, the Chancellor of the Smithsonian, Chief Justice of the Supreme Court Edward D. White, appointed a committee consisting of Bell as chairman; Democratic Senator William J. Stone of Missouri; Republican Representative Ernest W. Roberts of Massachusetts; John B. Henderson, Jr., regents, and Dr. Charles D. Walcott, secretary. Walcott later reported that the object of the committee was "...to prepare a memorial to transmit to Congress

31. Extract From Proceedings of the Board of Regents of the Smithsonian Institution, at the annual meeting held December 10, 1914.
in relation to a national advisory committee for aeronautics in the United States."  

The body initially convened on January 30, 1915, in the committee room of Senator Stone. By this time, most of the groundwork for the proposal to Congress already had been completed. Walcott submitted to the committee a draft of a "memorandum in relation to the Langley Aerodynamical Laboratory, and the desirability of the appointment of a national Advisory Committee for Aeronautics." He also went to the Capitol that day to confer with Representative Roberts of Massachusetts, a member of the Smithsonian Board of Regents and the committee on the Langley Laboratory, concerning the introduction of a joint resolution in Congress to establish an advisory committee.


33. Extract From Proceedings of the Board of Regents of the Smithsonian Institution, at the annual meeting held December 10, 1914; Hunsaker, Annual Report of the Smithsonian Institution, 1955, 245; Bonney, Unpublished manuscript with notation, "For Smithsonian, 7/18/55," NHA.

34. C. D. Walcott to A. G. Bell, Chairman, Committee on the Langley Aerodynamical Laboratory, January 30, 1915, NHA.

35. "Documentary History of the National Advisory Committee for Aeronautics," Prepared by the Smithsonian Institution, 54.
On February 1, 1915, Congressman Roberts introduced a joint resolution to establish a national advisory committee for aeronautics. In addition, the Smithsonian committee sent memorials on the need for a national advisory committee for aeronautics to the leaders of the two houses of Congress. The memorials asserted that an advisory committee "cannot fail to be of inestimable service in the development of the art of aviation in America." It was proposed that this committee would help to coordinate the "activities of governmental and private laboratories, in which questions concerned with the study of the problems of aeronautics can be experimentally investigated."

Prior to the introduction of the joint resolution, the committee decided that the most expeditious way to gain approval would be to attach the resolution as a rider to the Naval Appropriations Bill. One reason for this strategy was the possibility of open opposition by the Executive. The desire to avoid involvement in the war currently raging in Europe caused President


37. A. G. Bell and C. D. Walcott to President of the Senate and the Speaker of the House of Representatives, February 1, 1915, NHA.

Wilson to ask Americans to be "neutral in thought as well as in action." For this reason, the Smithsonian committee feared that Wilson would veto an independent bill as a breach in America's neutrality. 39

Another reason for referral of the resolution to the Naval Affairs Committee was that the Naval Appropriation Bill usually became the local "pork barrel" legislation. 40 Moreover, membership on the Naval Affairs Committee of Ernest W. Roberts, confidant of Walcott in making plans for an advisory committee, undoubtedly led the advocates of the joint resolution to prefer that House committee.

Perhaps the most important reason for this method was the opinion that in no other way could the legislation be enacted. Recognizing an existing Senate power, Walcott wrote to Republican Senator Henry Cabot Lodge of Massachusetts outlining plans for attaching the advisory committee for aeronautics proposal as a rider to the Naval Appropriation Bill. He told Lodge that Representative Roberts "did not think it would be possible to pass it [the joint resolution on the advisory

39. This possibility is pointed out in Hunsaker, Annual Report of the Smithsonian Institution, 1955, 245.

committee] through the House at this stage of the session, and suggested that the Committee on Naval Affairs of the Senate....insert it as an amendment to the Naval Appropriation Bill." If Lodge approved of this strategy, Walcott urged him to ask Senator Ben Tillman, Democrat of South Carolina, for assistance. 41 Walcott also promised to ask Senator Stone of the Smithsonian Regents "to actively interest himself in the matter." 42 This, of course, was open lobbying by a member of an independent agency of the government; but Walcott was never seriously criticized.

Certainly the most compelling reason for including this resolution in the Naval Appropriation Bill was the need for speed--the Sixty-third Congress was rapidly drawing to a close. Passage of a single bill authorizing an advisory committee before the adjournment on March 4 would have been very difficult indeed. After failing earlier, Walcott was eager to see his efforts become a reality. By means of attaching

41. Senator Tillman, as Chairman of the Senate Naval Affairs Committee, was an important ally. He promised to push the joint resolution on the NACA in the Senate as soon as the House passed it. See Tillman to Walcott, February 4, 1915, Secretary's File, 1909-1924, SIA.

42. C. D. Walcott to H. C. Lodge, February 20, 1915, Secretary's File, 1909-1924, SIA.
a rider to a bill that was certain of passage, Walcott and his associates felt they had their best chance of approval.

Navy Department approval of the rider on its appropriation bill was, of course, desired. The opinion of the Department was solicited by Democratic Representative Lemuel P. Padgett of Tennessee, Chairman of the House Naval Affairs Committee. A copy of the House Joint Resolution authorizing the advisory committee was sent to the Navy Department for its consent. Franklin D. Roosevelt, as Acting Secretary of the Navy, replied that he was very much in favor of the joint resolution:

I heartily indorse the principle upon which this joint resolution to authorize an advisory committee for aeronautics is based ....The great military necessity that has brought such rapid development of air craft about in Europe has demonstrated the practical utility of these vessels of the air, and has placed this country far behind in the use of air craft....We will be only too pleased to have an advisory committee that will bring about the cooperation of the private activities and thus greatly increase the effort in attacking the unsolved problems of aeronautics. It is believed that such a committee is the best means required in placing this country on an equality, or even in advance, of other countries in the development of aeronautics.

Roosevelt's strong endorsement contained only one reservation. He claimed that "representatives of the Government should always have the controlling interest
in the activities of this proposed committee." In this, the latter days of the progressive movement, there appeared to be fear that private industry might be able to gain control of a government agency and use it exclusively for its own advantage. When Walcott testified before the House Naval Affairs Committee, he agreed that the advisory committee, "should be controlled by the people in connection with the Government who are interested so as to have the Government actually in control of the committee." 

Interestingly, in the hearings before the House Naval Affairs Committee on the proposal for an advisory committee, only Walcott was asked to testify. It is ironical that this advisory committee, which became so very important in the development of aeronautical science, was defended by a man not even trained in aeronautics. This is not to say that Walcott's testimony was ineffective—though the fact that


44. See the testimony of C. D. Walcott in U. S. House, Naval Affairs Committee, Hearings, 1915, 63d Cong., 3d Sess., 1915, 1227.
Representative Roberts was a member of the committee surely made Walcott's task less demanding. 45

In his testimony before the Naval Affairs Committee, Walcott contended that the advisory committee would "bring all the suggestions on any one line together, and yet the work would be carried on in one place." In response to questioning about the role of private industry, he said that businessmen would "experiment in their own way, and later...have their results tested under direction of the advisory committee." 46 Walcott also used the example of the British advisory committee in his justification for such an agency in the United States. He asserted that the British committee organization indicated "what the work of the advisory committee should be." 47

Without much controversy, on March 3, 1915, the authorization to establish the advisory committee for

45. Despite Walcott's diligent work, a later chairman of the NACA was willing to give most of the credit to "the vision of the grand old man of aeronautics, Dr. William F. Durand." While it is true that Dr. Durand later played an extremely important role in the history of aeronautical research in the United States, to Dr. Walcott must go the majority of the credit for the establishment of the National Advisory Committee for Aeronautics. Vannevar Bush, Modern Arms and Free Men (New York: Simon and Schuster, 1949), 22-23.


47. Ibid., 1221.
aeronautics passed the Congress as a rider to the Naval Appropriation Bill. The provision copied much of the wording of the earlier declaration of the British Prime Minister in announcing the British advisory committee. Both stated the duty of the committee as supervising and directing the "scientific study of the problems of flight, with a view to their practical solution." The charge to both committees to "determine the problems... to be attacked...and discuss their solutions and their application to practical questions" was identical.

The Congressional provision for the NACA provided an appropriation of $5,000 per year for the first five years. This figure soon proved to be meaningless.

Once the legislation had been enacted, it was necessary to select and organize the advisory committee. Again Charles D. Walcott played a leading role. He conferred, on March 10, 1915, with Secretary of the


49. This language is found in both Public Law 271, 63d Cong., establishing the NACA; and the language establishing the British Advisory Committee, to be found in Hunsaker, Annual Report of the Smithsonian Institution, 1955, 246-47; see also Great Britain, Interim Report of the Advisory Committee for Aeronautics to Parliament, July 24, 1909.

Navy Josephus Daniels and Secretary of War Lindley Garrison about the organization and membership of the committee. Further, on the request of President Wilson, Walcott submitted his recommendations for membership on the committee. From the recommendations submitted by Walcott, on April 2, Wilson announced the appointment of the advisory committee. The members included:

- Brigadier General George P. Scriven, Chief Signal Officer, United States Army;
- Lieutenant Colonel Samuel Reber, aviation section, Signal Corps;
- Captain Mark L. Bristol, United States Navy;
- Naval Constructor Holden C. Richardson, United States Navy;
- Dr. Charles D. Walcott, Secretary, Smithsonian Institution;
- Mr. Charles F. Marvin, Chief of the United States Weather Bureau;
- Dr. Samuel W. Stratton, Chief of the Bureau of Standards;
- Mr. Byron R. Newton, Assistant Secretary of the Treasury;
- Professor William F. Durand, Leland Stanford University;
- Professor Michael I. Pupin, Columbia University;
- Professor John F. Hayford, Northwestern University.


52. A copy of these recommendations, along with a brief biographical outline of each person is in "Documentary History of the National Advisory Committee for Aeronautics," Prepared by the Smithsonian Institution. These men were generally considered the most knowledgeable and interested in aviation in the country.
At the request of Secretary of War Garrison, the first session of the committee met in his office on April 23, 1915. At this meeting the word "national" was appended to the committee's title—which had not been the case in the authorizing legislation—thus setting the formal title as the National Advisory Committee for Aeronautics (NACA). At the first meeting the members elected Brigadier General Scriver chairman of the Committee and Naval Constructor Richardson, secretary. They also established an executive committee, with Walcott as chairman, to carry on the actual work of the full Committee. Whereas the latter group met only twice each year, the seven-man executive committee met at least monthly and more frequently whenever there was need.  

Shortly after the first meeting, on June 23, John F. Victory was retained as the Committee's first employee in the position of clerk. No one could have


55. Victory became Assistant Secretary in 1917, Secretary in 1927, and Executive Secretary in 1945. Prior to his retirement in 1960, he spent his entire career in the service of the National Advisory Committee
anticipated the important role Victory would take in the
growth and development of the National Advisory Committee
for Aeronautics.  

Many problems confronted the Committee in conducting a scientific investigation of aviation. There
was no plan by the Committee to construct or operate airplanes, only a desire to make scientific investiga-
tions of the principles of flight. Walcott assured one interested observer that construction and operating
activities would be "left to the Army and Navy and to individuals." Naturally, however, the Committee was
desirous of getting on with its investigations; its foremost problem at its inception was the establishment
of its own laboratory where it could conduct investiga-
tions. Although other government-owned and operated
laboratories were available to initiate a few of the

for Aeronautics and the development of American aviation. His influence permeates the entire history of the NACA
and the Langley Laboratory. For the letter requesting authorization to hire him see H. C. Richardson to
Secretary of the Navy, June 14, 1915, NHA; Hunsaker; Annual Report of the Smithsonian Institution, 1955, 248;

56. All members of both the full and executive committees (and later technical subcommittees) of the
National Advisory Committee for Aeronautics served without compensation other than travel expenses.

57. C. D. Walcott to Alan R. Hawley, President of the Aero Club of America, April 7, 1915, Secretary's File,
1909-1924, SIA.
experiments, no single center existed at which to undertake exclusive and exhaustive research in aeronautics. This then was the original intention of the NACA—to build and equip its own laboratory and begin full investigation of the aerodynamic characteristics of flight.
CHAPTER III

CREATION OF AN NACA LABORATORY, 1915-1920

Following the appointment of a National Advisory Committee for Aeronautics, the Committee members realized that the next logical procedure would be construction of a laboratory. An agency laboratory would be necessary to conduct detailed fundamental research in aerodynamics. ¹ Earliest experiments completed under NACA contract were conducted at the Bureau of Standards and university laboratories. ² Since it was improbable that the NACA itself could acquire the funds to purchase land and build a laboratory thereon, the most obvious course of action in this venture was to gain the cooperation of the armed services.

The armed forces initiated some aeronautical activities prior to establishment of the NACA. The Army had created an air service and the Navy had

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¹. In a 1916 report on "Nomenclature for Aeronautics," issued by the NACA, the name "airplane" was substituted for any "form of aircraft heavier than air which has wing surface for sustentation, with stabilizing surfaces, rudders for steering, and power plant for propulsion through the air." Thus the word "aeroplane" was dropped. Philadelphia Inquirer, October 28, 1916.

². See for instance, the technical reports published in conjunction with the NACA 1st Annual Report, 1915.
established a small aeronautical experimental plant at the Washington Navy Yard. This modest laboratory, "for the development of aviation for naval purposes," was initially financed by a $25,000 Congressional grant in 1912.  

This facility occasioned Dr. Walcott some difficulty later when he was required to defend the NACA against the charge that its proposed laboratory might duplicate investigations undertaken by the Naval laboratory. Walcott testified that no duplication existed because Captain Mark L. Bristol, Commander of the Navy Air Service, and H. C. Richardson, Naval Constructor, were both members of the Advisory Committee. "On the contrary," Walcott stated, "if problems come before the committee that require investigation they endeavor to ascertain whether it will be possible to carry on that investigation in the Navy Department or in the Bureau of Standards or somewhere in connection with Government work."  

In 1915, at the time of the submission of its first report to Congress, the NACA, through its chairman


Brigadier General George P. Scriven, asserted that "one of the first and most important steps to be taken in connection with the committee's work is the provision and equipment of a flying field." The Committee also called for the acquisition of "aeroplanes and suitable testing gear for determining the forces acting on full-sized machines in constrained and in free flight." No mention was made on how the airplanes would be acquired.

Research proposed by the NACA, to be carried out at this projected laboratory, however, was not entirely for military purposes. The Committee recognized that during the period of war in Europe, and possible American involvement, military preparedness was important, but, following the war, "there will be found available classes of aircraft and a trained personnel for their operation, which will rapidly force aeronautics into commercial fields, involving developments of which today we barely dream." This declaration was intended to lay the foundation for continued appropriation requests for the post-war period—when experimentation could no longer be justified on military grounds. For this reason, it was important to cite the commercial benefits to be

derived from NACA research. Also President Wilson hoped to keep the country out of the European conflict and military preparedness might prove to be of limited value. Hopefully, however, the commercial benefits of an NACA laboratory would add emphasis and further credibility to the proposal for a research laboratory.

Furthermore, the NACA pointed out, investigation conducted by American colleges then offering courses in aeronautical engineering was better designed to satisfy curiosity than to meet the requirements of engineering. Manufacturers, with their interest in fulfilling government standards or creating popular demand, were no better prepared, nor financially able to conduct any serious research in aerodynamics. If this research was to be accomplished, the NACA, at its own laboratory, would have to be the agency to carry out the program.

7. The foremost university offering training in aeronautical engineering was the Massachusetts Institute of Technology. Jerome C. Hunsaker, Assistant Naval Constructor, was detailed to MIT by Secretary of the Navy Daniels in June 1913 to develop courses in aerodynamics. Walter T. Bonney, Unpublished manuscript with notation, "For Smithsonian, 7/18/55," NASA Historical Archives (NHA); Jerome C. Hunsaker, "Forty Years of Aeronautical Research," Annual Report of the Smithsonian Institution, 1955, 244.

officials asserted in budget hearings that greater efficiency could be attained by centralizing research than by waiting for the various manufacturers to provide their own laboratories. "One of the reasons why this committee was established," Dr. S. W. Stratton testified, "was to coordinate all of that work, and the committee was only to do those things that were not done elsewhere." 9 Despite Stratton's assertion that the NACA's primary interest was "to coordinate," agency officials were extremely interested in the establishment of a field laboratory.

The Committee encountered a problem in that few Congressmen, other than those directly involved, were aware of the NACA or of its proposal to build a research laboratory. During Senate hearings on aircraft production in 1918, not a single member of the NACA was called to testify, and one Senator, James A. Reed of Missouri, recalled that "there was a National Advisory Committee

9. U. S. House, Committee on Appropriations, Independent Offices Subcommittee, Hearings, 1920, 65th Cong., 3d Sess., 1919, 102. (Hereafter cited as U. S. House, Independent Offices Subcommittee.) On January 1, 1917, the Comptroller of the Treasury held the NACA to be an Independent Agency, thus the budget estimates for fiscal 1919 were referred to the House Committee on Appropriations instead of the Committee on Naval Affairs as had been the case to that time. William E. Stoney, Jr., "The NACA From Birth to Death," Unpublished manuscript, 1962, NHA, 10.
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for Aeronautics at one time."10 This apparent lack of knowledge or interest in the Advisory Committee surely hampered the NACA in appropriation requests for the construction of a laboratory.

Congressional apathy was only one of the problems faced in the establishment of a research laboratory under the direction of the National Advisory Committee for Aeronautics. The NACA could not by itself acquire a large enough appropriation to purchase land and construct a laboratory thereon. For this reason, the Army and Navy were consulted with reference to the possibility of construction of a joint experimental station.11 In its appropriation request for 1916, the Committee asked for $85,000; $53,580 of which it earmarked to begin construction of a field laboratory, justifying this request by the argument that research would be "coordinated as a part of the defense plans."

It was assumed at this stage that land in or near


11. George W. Gray, Frontiers of Flight (New York: Alfred A. Knopf, 1945), 13. Despite agreeing to cooperate with the NACA, the Navy was carrying out its own investigation for a site. There was no reason to believe the Navy would acquiesce in joint occupation with the Army and the NACA. See H. C. Richardson to C. D. Walcott, December 4, 1916, Secretary's File, 1909-1924, Smithsonian Institution Archives (SIA).
Washington would be available to carry out the desired experimentation. Subsequent considerations were to prevent the location of the laboratory in Washington.

Only the War Department, because of its relatively large appropriation, had sufficient funds with which to purchase land for an experimental station. It was primarily for economic reasons, therefore, that the National Advisory Committee for Aeronautics determined to follow the War Department's lead. Cooperation between the Army Air Service and the NACA had been excellent to this point and, since the Air Service was represented on the NACA, this allowed continuous communication. Congress took the first step when, in August, 1916, it directed the Secretary of War to investigate various military reservations in an effort to find one which would serve as an aeronautical experimental station. If none could be found, the Secretary was to use the $300,000, which Congress had


provided for the purchase of such land as might be needed. Since few appropriate sites were available on existing military posts, the Army appointed a Board of Officers in September, 1916, to select a site for the experimental station.

Members of the NACA, especially Walcott, knew that their best chance to obtain land for a laboratory was in cooperation with a new station being considered by the Army Air Service. Therefore, the NACA Executive Committee passed a resolution in early October that "a subcommittee be appointed to consider the needs of this committee as to site for experimental work, with authority to visit and inspect such sites as may be necessary, and to secure the cooperation of the War and Navy Departments and the Weather Bureau for the selection of sites for their own use." NACA members named to this subcommittee were Drs. Walcott, Stratton, and Marvin. The War Department answered Walcott's

14. Public Information Office Files, Langley Research Center (LaRC).

15. Members of the Army Board of Officers were Lt. Col. G. O. Squier, Capt. T. D. Milling, Capt. V. E. Clark, and Capt. R. C. Marshall, Jr. See NACA 3rd Annual Report, 1917, 20; and correspondence between Board of Officers and NACA in Headquarters Correspondence, 1916-1935, Box 1, Record Group (RG) 255, National Archives (NA).

16. NACA Executive Committee Minutes, October 9, 1916.
request for cooperation by declaring that "it will be most agreeable to the Signal Corps to give the Advisory Committee the benefit of its inquiries and conclusions." More specifically, the War Department agreed to joint consultation with the NACA Subcommittee and representatives of the Navy Department on the selection of a proving ground, and named Brigadier General George P. Scriven and Lieutenant Colonel George O. Squier as its representatives.

With the addition of Lieutenant John H. Towers, Lieutenant Jerome C. Hunsaker, Naval Constructor H. C. Richardson from the Navy Department, and Dr. Charles F. Marvin as representative of the Weather Bureau, the committee to choose a site was completed. Of immediate importance was the determination of characteristics for the site to be chosen. It was agreed that the site should be: (1) on level, cleared, well-drained ground adjacent to open water; (2) not less than two miles in length and a mile or more in width; (3) close to rail

17. C. D. Walcott to Secretary of War, October 9, 1916, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

transportation; (4) easily accessible to Washington; (5) in a healthy location; (6) of a mild climate; and (7) of a reasonable land cost.  

In the search for a location for the experimental station and proving grounds many sites were inspected. The Army officers disguised themselves as hunters and the Navy men as fishermen when making their inspections to prevent the raising of land prices. Although the advice of the NACA had been solicited, the inspection made by Drs. Ames, Walcott, Stratton, and Marvin of the place selected came after the selection had actually been made. It was assumed throughout, however, that "any site selected...may be made available to the committee."  

On November 9, 1916, representatives of the War and Navy Departments met with the NACA Executive Committee and informed them they had selected a site for the experimental station four miles north of


20. John F. Victory, interview with Captain Alfred F. Hurley, U. S. Air Force Academy, c. 1962, 8. Copy in NHA. It had been estimated that in developing the station the Army would expend approximately $1,472,900. Unsigned document in Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

Hampton, Virginia. The following day the Board of Army Officers formally requested the NACA to concur with their selection and to add the Committee's recommendation for the purchase of this land. Following this notification, the NACA made plans for an inspection of the site on November 18, in the company of the Army Board of Officers, two Naval officers and the Secretaries of War and Navy. The NACA also wrote the Surgeon General inquiring about health conditions in the Hampton area. The Public Health Service informed the NACA that its investigation of health conditions in the Hampton vicinity showed that the only disease which should be given particular attention in judging suitability of the area for a research laboratory was malarial fever. However, the prevalence of malaria in the Hampton area was no greater than in most other tidewater sections of the Atlantic Coast south of Washington.


23. Arrangements for this inspection trip were made by Hunter R. Booker, President of the First National Bank of Hampton, who held a purchase option on the land under consideration. R. C. Marshall, Jr. to H. R. Booker, November 16, 1916, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

24. A. H. Glennan, Acting Surgeon General, to H. C. Richardson, November 18, 1916, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
Furthermore, the consulting engineer in the office of the Chief Signal Officer said the area was "an ideal one for the intended purpose." 25

Following the inspection of the site on November 18, Dr. Walcott wrote the Army Board of Officers indicating NACA agreement with the choice of the Hampton site for the Army experimental station. Walcott also pointed out that it "would be advantageous to the development of the art of aeronautics if the experimental stations and proving grounds of the War and Navy Departments, and the Advisory Committee, could be brought in close proximity, if not on the same plot of ground." 26

With the unanimous agreement of all interested parties, the War Department purchased 1,650 acres of land from three men from Elizabeth City County—Harry H. Holt, Hunter R. Booker, and Nelson S. Groome—for $290,000. The deed was executed on December 30, 1916. The three men had taken options on enough land to have been able to offer the government up to 2,000 acres. 27

25. Henry Souther to H. C. Richardson, November 28, 1916, Secretary's File, 1909-1924, SIA.


Though the Advisory Committee was not yet assured of being assigned a portion of this land, it requested funds from Congress to begin construction of its proposed laboratory at the Army site.\(^{28}\)

On December 12, 1916, the NACA formally requested a portion of the land which was to become Langley Field,\(^{29}\) for use as its own aeronautic proving ground.\(^{30}\) William M. Ingraham, Acting Secretary of War replied that "this Department heartily approves your requests." He assured the Committee that the War Department greatly valued the "assistance and advice...in connection with our experimental work."\(^{31}\) A more specific request for land on which to build a laboratory, hangar, experimental


\(^{29}\) The name "Langley Field" was not designated officially until August 7, 1917, the site being known as the "Aviation Experimental Station and Proving Grounds" to that time. Months earlier, however, *Aviation* magazine stated that "the station will be known as 'Langley Field.'" See "Site Recommended for 'Langley Field,'" *Aviation and Aeronautical Engineering*, I, No. 12 (January 15, 1917), 396; "The Langley Story," 50th Anniversary Booklet, Langley Air Force Base, 1966, 2-3.

\(^{30}\) S. W. Stratton to Secretary of War, December 12, 1916, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

and power plants at the Hampton site was made by the NACA in February of 1917. Brigadier General Squier, Chief Signal Officer, answered this request saying it would not be agreeable to assign such space "until the work of preparing Langley Field is in a more advanced state." 

This exchange of letters was not considered a formal assignment of the land, and an official statement designating land was solicited in August, 1917, and again in late 1918. At the time of the latter request, the research laboratory building had already been erected and the first wind tunnel was under construction. Finally, in April, 1919, Major General Charles T. Menoher, Director of the Air Service, wrote the Acting Secretary of War recommending that the "portion of Langley Field known as Plot 16 be definitely

32. NACA Executive Committee Minutes, February 10, 1917; C. D. Walcott to Secretary of War, February 13, 1917, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

33. G. O. Squier to C. D. Walcott, March 1, 1917, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

34. W. F. Durand to G. O. Squier, August 29, 1917, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

35. C. D. Walcott to Secretary of War, December 17, 1918, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
set aside for use by the National Advisory Committee for Aeronautics for their purposes in constructing laboratories or other utilities necessary in scientific research and experiments in the problems of flight."

Acting Secretary of War Benedict Crowell approved this recommendation on April 24, 1919.36 President Wilson had also approved the construction of a laboratory by the NACA, saying that its "plans for enlarged activities contemplated through its laboratories and scientific staff at Langley Field...have my hearty approval."37

At last the National Advisory Committee officially had obtained land for its laboratory.

Following the informal acquisition of land in 1917, the NACA had to appoint an architect and determine which buildings to construct. On March 8, 1917, therefore, the NACA appointed a Committee on Buildings, Laboratories, and Equipment to consist of Dr. Stratton, Dr. Ames, Captain Clark and Lieutenant J. H. Towers.38

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36. Memo, C. T. Menoher to Acting Secretary of War, April 22, 1919 (with notation of approval), Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.


38. NACA Executive Committee Minutes, March 8, 1917.
committee soon decided that the immediate needs were: (1) a research laboratory building; (2) a wind tunnel; and (3) an engine dynamometer laboratory. Although the Army had chosen Albert Kahn of Detroit as its chief architect for the base, the NACA buildings were designed by the firm of Donn and Deming. A contract for the construction of the NACA research laboratory building was signed with the J. G. White Engineering Corporation of New York, the firm which also held contracts for construction of the air service buildings at Langley Field. Excavation for the first NACA building, estimated to cost $80,900, began on July 17, 1917.

The research laboratory building was designed to house the executive offices, drafting rooms, photographic, physical and chemical laboratories. As a unit, the principal function of the structure was to "serve the needs of the aerodynamical laboratory and the engine dynamometer laboratory," where the

40. John H. DeKlyn to S. W. Stratton, July 17, 1917, NHA.
41. NACA Executive Committee Minutes, July 12, 1917; John F. Victory, "Day Book," Biography File, Box 34, RG 255, NA.
experimental work would take place. 42 The building was so designed to permit the addition of two wings of the same size as the original edifice at a later date.

The second authorized structure was a building specifically designed to contain a wind tunnel of the atmospheric type with a 5-foot wind stream. Authorized in November, 1917, 43 plans for its construction were approved in April of 1918. 44 This atmospheric wind tunnel was equipped with a thrust torque dynamometer "for propeller investigations and for determining the effect of the fuselage form upon propeller efficiency." A force balance and dynamometers were both to be suspended from an overhead platform into the wind stream. The tunnel was to be powered by a 250-horsepower motor and designed "for air velocities up to 130 miles per hour with the 5-foot section." 45

The third building to be constructed by the NACA at Langley Field was an engine dynamometer laboratory. In this laboratory, internal combustion engines were to


43. NACA Executive Committee Minutes, November 15, 1917.

44. Ibid., April 29, 1918.

be tested, and research to be carried forward for the advanced development of aircraft engines. A request by the NACA authorizing the Quartermaster Corps to construct this laboratory at a cost of $55,000 was approved on May 24, 1919, by Secretary of War Newton D. Baker.

To build the last structure a four-section steel airplane hangar was utilized. It was necessary to construct the laboratory apart from the other structures because the engine testing for which it was to be used was said to be "very noisy and heavy work." Equipment to be installed in the laboratory included a 300 to 400 horsepower electric dynamometer, a 40 to 70 horsepower electric dynamometer and a 2½ horsepower bench electric dynamometer. Pending proposed erection of a power plant by the Army, a 200 to 300 horsepower dynamometer was used as a generator to provide power both in the dynamometer laboratory and the wind tunnel. Shortly after

46. Construction of the laboratory was authorized April 10, 1919. NACA Executive Committee Minutes, April 10, 1919.

47. C. D. Walcott to Director of Air Service, April 18, 1919, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA. This letter contains the notation of approval by Secretary Baker.


being placed in operation, it was discovered that the laboratory, constructed of steel, was "very cold in the winter time" and money was requested for a more permanent structure. 50

A portion of the building activities, which had been planned prior to American entry into the war, was curtailed during hostilities. 51 Another modification of the original plans was imposed by military authorities who informed the NACA that they were going to assume all construction work at Langley Field in August, 1918. 52 John F. Victory, in charge of administration of the NACA Washington office, felt that if this included construction of the Committee's wind tunnel building it would provide a considerable saving for "there will be no way of charging the time of soldier labor." 53


52. Official notification of the Army take-over of construction is in C. G. Brown, Captain, Air Service, to J. F. Victory, August 7, 1918, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA. The NACA Executive Committee accepted this by resolution. See NACA Executive Committee Minutes, August 8, 1918.

53. J. F. Victory to C. D. Walcott, August 5, 1918, Biography File, Box 37, RG 255, NA.
Although none of the original buildings were opened for use until 1919, as early as April, 1918, the Committee stationed its first employee at Langley Field. No single head of the laboratory was officially named until 1922, but John H. DeKlyn exercised effective management in his position as Engineer in Charge of Buildings and Construction. DeKlyn, hired as a technical assistant to the NACA in 1916, supervised the initial construction of the laboratory buildings at Langley Field. Sharing a portion of the authority at the laboratory with DeKlyn were Edward P. Warner, Chief Physicist, and Leigh M. Griffith, Senior Staff Engineer.

This arrangement was rather short-lived. In February of 1920, after a visit to Langley, John F. Victory reported to George W. Lewis, NACA Executive

54. NACA 4th Annual Report, 1918, passim. At the time of the submission of this report on November 29, 1918, no facilities of the NACA at Langley Field were yet open to use.

55. Dr. S. W. Stratton testified in April, 1918, that of the 21 employees of the Advisory Committee, only one was then at Langley Field. He said, however, that the following year the Committee expected to have 17 employees at Langley Field. In the early years, testimony before the House Independent Offices Subcommittee covered virtually every individual employed by the Committee. For example see U. S. House, Independent Offices Subcommittee, Hearings, 1919, 65th Cong., 2d Sess., 1918, 474-75.

56. See the correspondence between J. H. DeKlyn and H. C. Richardson, October 20-December 6, 1916, NHA.
Officer,\textsuperscript{57} that little cooperation existed between DeKlyn, Warner and Griffith. Victory asserted that DeKlyn had "subordinated the Committee's best interests and neglected his duties." Of the clerk in DeKlyn's office, M. M. Colvin, Victory stated that he was "incompetent, irresponsible, and lacks initiative." Victory recommended that DeKlyn and Colvin both be relieved of their duties as quickly as possible, even though DeKlyn had already submitted his resignation.\textsuperscript{58} Shortly after the departure of DeKlyn in February of 1920, Griffith suggested that one man be placed at the head of the laboratory and nominated himself. This change would, Griffith argued, have the approval of Warner.\textsuperscript{59} Finally, on November 1, 1922, Griffith was officially named Engineer-in-Charge of the Langley Laboratory,\textsuperscript{60} a post he held for more than three years.

\begin{itemize}
\item \textsuperscript{57} Lewis' title was changed in 1924 from Executive Officer to Director of Aeronautical Research, in which capacity he served to his retirement in 1947. Hunsaker, \textit{Annual Report of the Smithsonian Institution, 1955}, 255-56.
\item \textsuperscript{58} J. F. Victory to G. W. Lewis, February 16, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
\item \textsuperscript{59} L. M. Griffith to NACA Headquarters, March 31, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
\item \textsuperscript{60} E. M. Emme, \textit{Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915-1960} (Washington: National Aeronautics and Space Administration, 1961), 16.
\end{itemize}
Also during 1918 and 1919, the first minor experimentation was carried out by the NACA at its Langley Field laboratory (but as yet the laboratory had no official name). A flight instrumentation program was started. This program sought the development of instruments for measuring engine torque and rotational speed, propeller thrust, airspeed, and angle of attack. During the summer of 1919, the first flight research program was undertaken by the laboratory research team. An investigation was conducted on the lift and drag of the JN4H airplane. The results of these tests, made on two airplanes borrowed from the Air Service, were published in a NACA technical report, the first technical report written by Langley personnel. These tests were but the first of innumerable flight research projects which occurred at the Langley Laboratory.

Certainly the foremost problem in the early years of the laboratory was the relationship of the NACA personnel with military authorities and, more particularly, the Air Service commanding officer at


Langley Field. Because of the necessities evolving from the war, the Air Service had decided to conduct their aeronautical research at McCook Field, near Dayton, Ohio. This action was taken when the Army concluded that too much time would be dissipated waiting for the construction of Langley Field. Consequently, during the war, the Air Service restricted its use of Langley Field to train aerial observers, aerial photographers, and aviators. 63

In spite of the Army having an experimental station at McCook Field, the NACA assumed that original plans for an Air Service experimental station and proving ground at Langley Field would be reinstituted following the war. 64 As late as 1919, Dr. Stratton testified that "what we call the engineering station at Langley Field will no doubt be developed into a proving ground by the Army." 65 The NACA thought it more expeditious to investigate the problems of flight at one location. Furthermore, the Army's Chief Signal Officer, Major

63. Sweetser, American Air Service, 116-17, 131-32; NACA 4th Annual Report, 1918, 24. Also, transportation problems were said to play a part in the move to McCook Field. See U. S. Senate, Committee on Military Affairs, Hearings on Aircraft Production, 65th Cong., 2d Sess., 1918, 742-43.


General George O. Squier, praised NACA efforts during the war and said that with the construction of the Langley Field laboratory, "the work of aeronautical research will be expanded...to cover present and future problems vital to the science and art of aeronautics." In view of these factors, it was surprising that bitter feelings developed between the NACA personnel and the Air Service.

One Air Service officer concerned with aeronautical research, Colonel Thurman H. Bane, Chief of the Air Service Technical Division and also a member of the NACA, recommended a course of action which would have effectively abolished the NACA laboratory at Langley Field. Bane, in a memorandum to Major General William L. Kenly, Director of Military Aeronautics, praised the NACA's efforts to develop facilities for aeronautical research. He noted, however, that they would duplicate the work conducted by the Technical Division of the Air Service.

Colonel Bane also criticized the dual control which would emerge if the NACA were given space at


67. Thurman H. Bane to William L. Kenly, January 15, 1919, NHA.
Langley Field. He recommended instead that "the control of the field and all experimentation at the field remain with the Air Service." He further suggested that "such research personnel as is now maintained by the committee or shall in the future be maintained, shall be loaned to the Air Service for their use as consulting engineers. The personnel of the National Advisory Committee for Aeronautics," Bane continued, should "maintain no equipment of any nature at the experimental station and shall use exclusively such equipment as will be purchased by the Air Service...[and]...the entire personnel...while at the experimental station shall be subject to the orders of the Chief of the Technical Division of the Air Service." Bane did advise, wisely, that "diplomacy requires a very careful presentation to the NACA." He felt the ideas should be presented in a conference between the NACA and the Air Service rather than by correspondence. 68

Caution certainly was necessary, because the acceptance of this proposal would have meant the effective end of the NACA as an independent agency and would have transformed Langley Field into a purely military installation. Fortunately, for the NACA at

68. Ibid.
least, the Air Service command responded that "it is not deemed advisable to bring this point to an issue at the present time." Though it is doubtful that the NACA would have accepted this plan, the publication of it would have considerably strained relations between the Committee and the Air Service.

The problems of actual control at Langley Field were finally settled in April of 1919. Major General Charles T. Menoher, Director of the Air Service, wrote recommending to Dr. Walcott that command of the field should be under an Air Service officer. Menoher agreed, however, that there would be no interference with the daily work of the Committee. He also displayed insight by asserting that "cooperation of the Commanding Officer and the Chief of the Advisory Committee personnel was essential" to the successful operation of the field.

In the summer of 1919 the greatest difficulties erupted with the Air Service Commander at Langley Field.

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69. L. H. Drennan (at the direction of Major General Kenly) to T. H. Bane, January 25, 1919, NHA.

70. C. T. Menoher to C. D. Walcott, April 10, 1919, and draft of memo, prepared by J. F. Victory for Menoher's signature, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA. On further plans for the take-over of the field by the Air Service, see William Mitchell to Director of Air Service, June 9, 1919, Correspondence 1919, Box 7, William Mitchell Papers, Manuscript Division, Library of Congress.

71. John H. DeKlyn reported to NACA Headquarters that great difficulties existed between NACA civilian
Most disturbing to the NACA was the problem of living quarters for its employees. Langley Field at the time was approximately four miles from the city of Hampton, Virginia, and a lack of transportation facilities made living in the city a substantial hardship. Many bachelor employees were in fact sleeping on cots in the research laboratory building. Although the Army had asserted previously that quarters could not be made available, Walcott repeatedly asked for living facilities. He pleaded with the Army to make an exception to its rules and provide heat, light, and telephone services, along with quarters for the Committee's personnel. He also requested commissary privileges on the base for the NACA employees.

In July of 1919 it appeared that the problem of quarters was solved when the Director of the Air Service announced that some quarters would be assigned to the Langley civilian employees. The Air Service recommended employees and the military commander at Langley Field, Captain E. J. House. J. H. DeKlyn to J. F. Victory, June 12, 1919, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.


73. C. D. Walcott to Director of the Air Service, June 10, 1919, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
that the Committee construct living quarters on Plot 16 as soon as possible. This agreement was on a temporary basis, however, as Colonel Oscar Westover advised the NACA that the Judge Advocate General of the Army had ruled that the Army could not furnish heat, lights, telephone service, or quarters to the NACA people. This decision forced the NACA to continue housing some of its personnel in the research laboratory building and to make other arrangements for the remaining employees. Later the NACA requested funds to build a house for some of its bachelor employees but this facility was never built.

Relations with the military commanders at Langley Field continued to be strained throughout the early years when the Laboratory shared occupation of the base. At the time of the dedication of the Laboratory in June, 1920, only one Langley-based flying officer attended the ceremony. Colonel William N. Hensley, the base Commanding Officer, prevented other officers from attending by "specific orders to remain at their

74. H. C. Pratt to National Advisory Committee for Aeronautics, July 31, 1919, NHA.

75. Oscar Westover to NACA, September 16, 1919, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

posts until after 5:00 PM." Colonel Hensley, himself, did not attend the dedication, although another strong critic of the NACA, General William "Billy" Mitchell, was present. NACA Senior Staff Engineer, L. M. Griffith claimed that at a meeting of Air Service officers on June 15, 1920, the "possibility of ousting the N.A.C.A. from the field" was discussed, and Colonel Hensley "promised to do everything within his power to bring this about." Colonel Hensley also charged that Griffith had been the cause of the antagonistic relations and suggested that Griffith be removed. John F. Victory investigated Hensley's accusations and concluded that "the Commanding Officer and General Mitchell...

77. L. M. Griffith to G. W. Lewis, June 17, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA. In spite of his actions, Dr. Ames, Chairman of the NACA Executive Committee, wrote Hensley thanking him for his cooperation. "The efficiency of our work at Langley Field depends in the end...upon the degree to which you give us your support." J. S. Ames to W. N. Hensley, June 21, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

78. Newport News Daily Press, June 12, 1920. This was the only time until shortly before his death, that Mitchell visited the Langley Laboratory. John F. Victory interview with A. F. Hurley, U. S. Air Force Academy, June 29, 1962, 1-2.

79. L. M. Griffith to G. W. Lewis, June 17, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

80. W. N. Hensley to General (most likely Mitchell), August 11, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
... anxious to have the Committee move from Langley Field."  

Mitchell's opinion of the NACA and the laboratory at Langley Field was entirely clear. In 1920 he wrote the Military Attaché at the American Embassy in Paris: "It is difficult to handle this National Advisory Committee in any way. It does no good here nor any other place that I can see and there is a project of law now for its abolishment which I hope will take place." Mitchell perhaps can be excused for his lack of foresight, as his forte was advancement of the public realization of the value of air power. He was not considered an expert in aeronautical technology.  

In 1920 Mitchell also claimed that a British Air Service officer named "Major Dale" had been flown over the coastal area by NACA personnel. Asserting that his information on "Major Dale" came from the Commanding Officer at Langley Field, Mitchell argued that this was

81. J. F. Victory to J. S. Ames, September 2, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.  

82. William Mitchell to T. B. Mott, April 22, 1920, Correspondence 1920, Box 8, Mitchell Papers.  

a breach of the secrecy of the coastal defenses of the United States and should immediately be stopped. Responding to this accusation, Leigh M. Griffith reported that no "Major Dale" had ever been at the NACA laboratory though a Major Normand of the British Air Service had visited with the full knowledge and consent of Colonel Hensley. Griffith pointedly did not respond to Mitchell's charge of violation of coast defenses, however, as Major Normand had been flown over the area.

The only other evident, direct relation between Mitchell and the NACA was a request early in 1921 by the General that the NACA engineering staff vacate their quarters at Langley Field by February 1. Mitchell, at a meeting with the NACA Executive Committee said the Air Service could use the NACA buildings and would pay $200,000 for them through appropriate Congressional legislation. This confrontation provided part of the

84. William Mitchell to Director of Air Service, June 29, 1920, Correspondence 1920, Box 8, Mitchell Papers.
85. L. M. Griffith to G. W. Lewis, July 2, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
86. NACA Executive Committee Minutes, January 27, 1921. Throughout 1921, Mitchell carried on much correspondence with Thurman H. Bane, concerning aeronautical research, but not once mentioned investigations being conducted by the NACA. See Correspondence 1921, Box 9, Mitchell Papers.
background to a later proposal for transferring the NACA field laboratory to Bolling Field.

By 1922, despite earlier difficulties, relations between NACA personnel at Langley Field and the Air Service Commander there had greatly improved. Colonel Charles H. Danforth was then Commanding Officer and, the change came primarily from the cooperative personalities of the NACA and military leaders at Langley Field. After this early period of hostility, relations between the military and the NACA remained cordial.

During the same period in which relations with the Army Air Service were quite strained, the Committee hoped the Navy might establish an experimental station contiguous to Langley Field. Soon after American entrance into the war, Walcott wrote Navy Secretary Josephus Daniels advising him to create a Naval experimental station near Hampton Roads. He suggested joint occupation with the NACA and the War Department at Langley Field, but said the decision would have to come from the Navy. The NACA had hoped, virtually from its beginning, that a joint Army-Navy-NACA laboratory could be created.

87. J. F. Victory to C. D. Walcott, August 1, 1922, Biography File, Box 37; and C. T. Menoher to C. D. Walcott, April 10, 1919, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

88. C. D. Walcott to Josephus Daniels, June 29, 1917, Biography File, Box 37, RG 255, NA.
As late as 1919, in testimony to the House Independent Offices Subcommittee, Dr. S. W. Stratton, NACA Secretary, asserted that since the war had ended, "it appears that the War and Navy Departments are going to join the committee in working out some of the fundamental scientific problems in regard to aviation." 89

The Navy had not yet decided on a course of action, but it denied any duplication of NACA experiments by citing Naval representation on the Advisory Committee. 90 Final consideration of Naval cohabitation of Langley Field came in 1920. A desire to experiment primarily with seaplanes, however, led the Navy to establish its experimental station across Hampton Roads at Norfolk, Virginia. 91 Although cooperation between the NACA and the Navy Department remained at a high level, lack of easily accessible transportation and communication facilities hindered close relations between researchers of the two agencies in the formative years of the Langley Laboratory.

The NACA, in 1919, concluded that it might be wise to remove the experimental station from Langley

90. Ibid., 106-07.
Field. This decision was partially the result of the
difficulties with the military. Because the services had
established their experimental stations elsewhere, John F.
Victory wrote that "the Committee finds it difficult to
secure or retain high-grade men at Langley Field...[as
there was]...little opportunity for the interchange of
ideas." Furthermore, the size of the labor force in the
area was limited, and supplies and equipment were somewhat
difficult to acquire.\(^92\) This handicap, of course,
was intensified by the obvious transportation uncertainty
in the region. To reach the laboratory from Washington
required an overnight boat trip with the nearest dock
approximately eight miles from the laboratory.\(^93\) Bolling
Field, an uncompleted parkway project in the District
of Columbia under War Department control, became the
leading site for the proposed relocation of the labora-
ty.\(^94\) In its 5th Annual Report, the NACA discussed
some of the problems at Langley and advantages of the
Bolling Field site.

\(^92\) J. F. Victory, "Memorandum Regarding the Use
of Langley Field by the National Advisory Committee for
Aeronautics," September 27, 1919, Headquarters Correspon-
dence, 1916-1935, Box 1, RG 255, NA.

\(^93\) Interview with Pearl I. Young, January 9, 1967.

\(^94\) NACA Executive Committee Minutes, July 25,
1919; J. F. Victory to C. D. Walcott, October 29,
1919, Headquarters Correspondence, 1916-1935, Box 1,
RG 255, NA.
The committee believe it uneconomical and unsatisfactory to remain at Langley Field. The same work can be carried on more efficiently, more promptly, and more economically at Bolling Field, where the work can be more closely watched by all members of the committee, and where the members of the engineering staff in charge of work can have ready access to the committee, to large libraries and other sources of information, constant communication with the Bureau of Standards, a more satisfactory market for labor and supplies and adequate power supply, and relief from the perplexing question of securing quarters at Langley Field or in Hampton or other near-by towns. Much direct effort is wasted in striving to accomplish results in the face of the difficulties encountered at Langley Field. The Army Air Service and the Naval Air Service are in accord with the committee in strongly recommending... the removal of the committee's research activities...to Bolling Field....There is an immense advantage to be gained from the conduct of scientific work in a center of education and learning, and where it would be possible to confer with visiting scientists. Work conducted at Bolling Field would also have the advantage of being accessible to Members of Congress.

The Committee requested the approval of Congress for the proposed move to Bolling Field. Somewhat contradicting this request, however, was the Report's appeal for funds, in which there was no apparent consideration of the proposed removal of the laboratory from Langley Field.96

Talk of moving to Bolling still flourished in 1920. The delay in making a decision was causing some

96. Ibid., 39.
stresses. G. W. Lewis, NACA Executive Officer, contended that the difficulties with Colonel Hensley were partially the result of the Colonel's knowledge of the possible move; also the unsure status was said to have caused some depression among the NACA employees at the laboratory. 97

No immediate Congressional authorization for the move was forthcoming, and by the spring of 1921, a tentative decision had been reached to keep the laboratory at Langley Field. In January, Dr. Ames reported many problems in the proposed move: Bolling Field was "far from completed," would be "fairly small," had "no sewage, gas, or other facilities...[and]... no present permanent buildings." Ames felt it would be "at least a two year wait" until the move could be accomplished and too much time would be wasted in restricting construction of new equipment and buildings for that length of time. 98 For these reasons, Drs. Ames and Stratton recommended that the NACA Executive Committee delay any premature move from Langley Field. 99

97. G. W. Lewis to L. M. Griffith, July 24, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

98. J. S. Ames to S. W. Stratton, January 29, 1921, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

99. NACA Executive Committee Minutes, January 10, 1921.
March, however, J. F. Victory was able to assure the laboratory's Chief Clerk that there was "no present probability that the Committee...[would]...remove its activities from Langley Field within the next twelve months."\textsuperscript{100} Besides, by 1922 the committee's investment in the Langley Field laboratory made a move far too expensive.

Despite the problems of its relationship with the Air Service and the possible move to Bolling Field, the NACA dedicated its laboratory at Langley Field in June of 1920. Earlier that year the Committee had passed a resolution to name its field station the Langley Memorial Aeronautical Laboratory in honor of the late Samuel P. Langley.\textsuperscript{101} Walcott wrote the President asking if there was any legal barrier to this name for the laboratory. Wilson referred the query to his Attorney General, A. Mitchell Palmer who advised that he knew of "no legal objection to the use of Dr. Langley's name" for the NACA field station.\textsuperscript{102}

\textsuperscript{100} J. F. Victory to F. E. Herbert, March 18, 1921, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

\textsuperscript{101} NACA Minutes, April 22, 1920.

\textsuperscript{102} C. D. Walcott to Woodrow Wilson, April 28, 1920; and A. Mitchell Palmer to Wilson, May 24, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.
With this approval, the Langley Memorial Aeronautical Laboratory [LMAL] was formally dedicated on June 11, 1920. Invitations to the ceremony were sent to men prominent in the development of American aviation. During the day of the festivities,\textsuperscript{103} Committee members were entertained by an inspection tour of the laboratory—the atmospheric wind tunnel was operated for the first time. Formal addresses were given by Dr. J. S. Ames, Chairman of the NACA Executive Committee, Major General C. T. Menoher, Director of the Army Air Service, and Rear Admiral D. W. Taylor, Chief Constructor of the Navy. Both Menoher and Taylor spoke of the help the NACA had been to their respective services.\textsuperscript{104}

Because the wind tunnel had just been opened and the engine dynamometer laboratory not yet completed, the experimentation carried out at Langley to the time of the dedication had been of a preliminary nature. But the NACA Committee on Aerodynamics had recommended research in three general areas at LMAL for the

\textsuperscript{103} The unofficial portion of entertainment expenses at the dedication—breakfast, lunch, catering services, pineapple sherbet, cookies, and invitations—were paid for by Lewis, Griffith, Warner and Victory ($22.11 each). Memo, J. F. Victory to Lewis, Griffith, Warner and Victory, June 16, 1920, Headquarters Correspondence, 1916-1935, Box 1, RG 255, NA.

\textsuperscript{104} NACA Executive Committee Minutes, June 11, 1920; \textit{NACA 6th Annual Report}, 1920, 8.
forthcoming year: (1) comparison of stability results from free-flight and wind tunnel tests; (2) the same comparison for performance results; and (3) research on airfoils, including control surfaces. Although not much had yet been accomplished at LMAL, the foundation had been laid for what became the finest aeronautical research laboratory in the United States before World War II.

CHAPTER IV

RESEARCH ACTIVITIES AT LANGLEY, 1920–1927

With the completion of the original plans for laboratory construction, NACA interest shifted to staffing the facility. It was essential, of course, to acquire an adequate staff to conduct the laboratory experimentation planned by the NACA. Hugh L. Dryden, one of the Directors of Aeronautical Research for the NACA, said that the "most important tool in aeronautical research, even more important than large wind tunnels, is the human mind."¹ The NACA appointed a Committee on Personnel in 1919 to "handle all matters relating to personnel, including the employment, promotion, discharge, and duties of all employees."² Owing to a limited budget, research which could as easily be conducted by existing Army and Navy laboratories was not assigned to the Langley Laboratory.³ In this manner, personnel was kept to a minimum.

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The majority of the engineers and technicians employed to serve at Langley were young, enthusiastic men. Their relative youth is partially attributable to the fact that there simply were no older, professionally trained men available. Formal university curriculum offerings in aeronautics had not been instituted until 1913, and then the Massachusetts Institute of Technology, Stanford University, and the University of Michigan produced almost all of the qualified personnel. Many of the men hired, especially in the 1920's, had been trained as electrical engineers, and developed an interest in aeronautics. Their contributions were essential to the development of the instruments necessary for the gathering of data.

For a young engineer, interested in doing aeronautical research, few other opportunities were available for the consummation of this desire. Little research was being conducted by the fledgling industry in the United States, and military investigations in aerodynamics were primarily of an applied rather than a


5. Interview with Pearl I. Young, January 9, 1967.
fundamental nature. Further, the starting salary with the NACA was attractive.

Many employees felt that an "apprenticeship" at Langley opened the way to greater status and higher salaries in industry. One engineer, now retired after a long career with the NACA and later NASA, commented that "two or three years of post-graduate experience at Langley would fit me for a job in the airplane industry. My work at Langley, however, proved sufficiently interesting and challenging that the urge to leave for a job in industry became greatly weakened." This statement is repeated often by men who had begun work at Langley with a similar idea in mind and who had spent their entire career with the agency.

So far as can be determined, the first Langley Memorial Aeronautical Laboratory (LMAL) employee was E. O. Bennett, who left after a very short time. F. H.


8. Other expressions of this kind are found in "Making America Independent in the Air," Mechanical Engineering, 45 (September, 1923), 516.

9. This remained the official name of the laboratory until 1948, when it was changed to the Langley Aeronautical Laboratory. In 1958, when the NACA formed the nucleus for the new National Aeronautics and Space Administration, the formal designation was changed to the present Langley Research Center.
Norton and E. P. Warner were among the earliest LMAL employees, although both soon left for work at MIT. Each, however, retained a strong interest in the activities of LMAL. 10 Within the first few years of laboratory existence H. J. E. Reid, Robert E. Mixson, and Pearl I. Young were employed, and each played important roles in Langley successes. 11 Most of the people, although selected through civil service examinations, originally became acquainted with Langley investigations through one of their college professors or a personal contact with someone in the NACA.

Working advantages at Langley included the accessibility of the most modern equipment with which to carry out the assigned research. In addition, the atmosphere of freedom of research and absence of pressure to earn a profit appealed to prospective employees. Furthermore, presidential support allowed Langley employees to feel a greater sense of efficacy in the work they were performing. President Coolidge, in his letter accompanying the 1925 NACA Annual Report, said that the

11. Interviews with Reid; Young; and Robert E. Mixson, January 11, 1967.
report should "dispel the impression" that America was falling behind in the technical development of aircraft.\textsuperscript{12}

Naturally the major difficulty in retaining the staff was the prospective loss of employees to industry and the geographical remoteness of the laboratory site. Hampton, Virginia, the nearest "city," was about four miles from the laboratory. Dr. Charles D. Walcott, NACA Chairman, complained in testimony to Congress that transportation was neither sufficient nor dependable enough to handle the demands of Langley employees.\textsuperscript{13} The Advisory Committee asked for funds to purchase an automobile to transport visitors, but it was also used as a conveyance for the Committee's employees at and around the laboratory.\textsuperscript{14}

Despite difficulties in finding willing and suitable employees, the staff grew steadily from five men in 1917, to one hundred twenty-nine by 1926.\textsuperscript{15} Events that year and in 1927, however, created great public interest in aviation and made the recruitment of personnel for the Langley Laboratory much easier.

\textsuperscript{12} New York Times, December 11, 1925, 12.
\textsuperscript{14} Ibid., 69th Cong., 1st Sess., 1926, 243.
\textsuperscript{15} Ibid., 242; Newport News Daily Press, January 7, 1926.
To direct the staff which was acquired, not an easy task as the men could be truly described as a "group of individuals," the NACA created the office of Executive Director (later Director of Aeronautical Research) in the Washington office of the agency. George W. Lewis, former professor of mechanical engineering at Swarthmore College, was engaged in November, 1919, to fill this post. At first it was thought that Lewis would direct aeronautical activities from an office at LMAL, but he soon discovered that he could be more effective by remaining in Washington.\(^\text{16}\) As Executive Officer of the NACA, Lewis was responsible for all the aerodynamic activity of the organization. Both the Executive and Full Committees of the NACA, along with the various technical subcommittees, were manned by appointed, unpaid members. Therefore Lewis was the only person whose time was exclusively devoted to NACA research.

He was responsible to insure that "research authorizations recommended and work planned by the subcommittees...[was]...carried out." He was also to make certain that reports on research were submitted "in proper form for distribution."\(^\text{17}\) To carry out this

\(^{16}\) H. J. E. Reid to J. C. Hunsaker, August 4, 1948, NASA Historical Archives (NHA).

function, of course, Lewis made himself familiar with the technology of the three branches of activity the NACA concerned itself with: aerodynamics, power plants, and materials. He kept himself aware of laboratory activities by frequently visiting Langley and discussing with as many of the staff as possible their research and the problems they might be encountering. Lewis, running technical affairs, and John F. Victory, overseeing administrative affairs and Congressional relations, were the two most influential men in the history of the NACA and, thereby, the Langley Laboratory.

Leadership at the laboratory itself was somewhat unstable until 1926. Following the dismissal of John H. DeKlyn as Engineer in Charge of Buildings and Construction, a short period of dual leadership existed. In 1922, Leigh M. Griffith was named Engineer-in-Charge. Edward P. Warner, who had held the position of Chief Physicist, left the laboratory for a teaching position at MIT. Griffith was primarily interested in power plant research and attempted to promote more experimentation

18. Told to the author in many, many interviews.
19. See Chapter III.
in that field during his tenure of office.\textsuperscript{21} The greatest need, however, was for basic data compilation on the aerodynamics of flight, for which Griffith was not sufficiently qualified. Dr. William F. Durand of Stanford University, one of the most highly respected figures in American aeronautics, had brought Griffith into the NACA from California, and Samuel W. Stratton, Secretary of the NACA, thought up the title "Engineer-in-Charge" for him.\textsuperscript{22}

By 1925, Griffith had lost favor with the Washington office to such an extent that a change in leadership at the laboratory was necessary. Complaints from Washington stated that an insufficient number of LMAL technical reports were forthcoming. J. S. Ames, Chairman of the NACA Executive Committee, and Lewis finally decided that a new Engineer-in-Charge would have to be appointed.\textsuperscript{23} Griffith, himself, perhaps aware that the end of his leadership was approaching, requested a leave of absence to devote himself to problems rising from his family's business interests in California.\textsuperscript{24}

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23. \textit{Ibid.}
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Griffith was told by Lewis before he left that he could not return to his former position at Langley, and remained in California.  

Two men were given a chance to show their potential as Engineer-in-Charge of the Langley Laboratory. Marsden Ware, who had been a chief assistant to Griffith and directed the power plant research, and Henry J. E. Reid, who was in charge of instrumentation research, took turns acting as temporary head of the laboratory. This was easily accomplished since the Langley staff in 1925 numbered only about 120 employees.

Soon it became evident to the staff that Reid was to be the new Engineer-in-Charge. His experience as head of instrumentation research had brought him into contact with, and given him an understanding of, all other divisions of the laboratory. Reid officially became Engineer-in-Charge of the Langley Memorial Aeronautical Laboratory on January 1, 1926. He directed all research at the laboratory from this time to his retirement in 1960. Indicative of the youth of


27. NACA Executive Committee Minutes, February 5, 1926.
the laboratory staff is the fact that Reid was only twenty-nine years old when he was named Engineer-in-Charge and had worked at Langley less than five years. 28 His contributions to the success of activities at LMAL are without peer in this history.

Below the Engineer-in-Charge, the organization of the laboratory was comparatively unstructured. The various research sections were not formalized and no true chain of command existed. 29 It was so informal that one man, Dr. Max M. Munk, virtually formed his own section and did his theoretical work with little direct supervision. He was not, of course, completely isolated, but few of the young men dared openly to contradict his theoretical calculations. 30

With this structure, problem organization was simplified. Requests for research often came from the

28. Interview with H. J. E. Reid.

29. Despite this, Representative William R. Wood (R-Ind.), intoned that the NACA would go the way of all governmental agencies as he saw them. "I have never yet seen one," Wood asserted, "that did not try and build up a big organization with highfaluting titles and corresponding salaries." U. S. House, Independent Offices Subcommittee, Hearings, 67th Cong., 2d Sess., 1921, 371.

military services, though many times the military acted as a conduit for some other interested party. A number of suggestions for research activity emerged from discussions during the meetings of the NACA Executive and Full Committees and its technical subcommittees. In addition, research proposals made by Langley engineers were given due consideration, and, finally, the aircraft industry requested investigations which it often supported financially.

Regardless of the origin of a research proposal, once it reached the laboratory a conference was held to discuss how the problem was to be approached. Also taken into consideration was the equipment to be used, what new instruments might be needed, perhaps how long to allow for the research, and the approximate cost of the project. Because of budget limitations, the cost factor often was closely watched throughout the progress of the research. Once the research organization had been agreed upon, meetings were held at regular intervals

31. Interview with Walter S. Diehl.


to insure continued progress along the procedure outlined in the original discussion.\textsuperscript{34} In this manner research on a particular project could be terminated at any point if preliminary investigation showed it to be of limited value. The cessation of a project did not require the formality occasioned by its initiation.\textsuperscript{35} A project could be easily terminated without extensive paper work. Until the laboratory staff grew to great size just prior to World War II, this system of organizing sections of the staff about individual problems remained substantially intact.

With a competent staff and a functioning organization, the Langley Memorial Aeronautical Laboratory devoted primary attention to the development of instruments. Earlier aerodynamic investigations in the United States were based, to a large extent, on guesswork. There was an obvious need for equipment with which to record accurately the forces acting on an airplane. Without recording instruments little advance in aeronautics was possible--one cannot conduct research on a phenomena which he does not completely understand.

\textsuperscript{34} "Making America Independent in the Air," \textit{Mechanical Engineering}, 45 (September, 1923), 516.

\textsuperscript{35} Interviews with Walter S. Diehl and H. J. E. Reid.
Fundamental research, which the NACA desired to accomplish as one of its major goals, had to be preceded by the gathering of accurate raw data on the dynamics of flight.\textsuperscript{36}

Even before any testing took place, the NACA announced its plans to place recording instruments on a plane to "determine the performance...of the machine in flight."\textsuperscript{37} In this manner, a body of scientific data could be collected and collated, and made available to aircraft designers. Because it would be impossible for an observer to record the information by hand during a flight, instruments had to be developed which could provide a permanent and accurate record of the test results on film drums.\textsuperscript{38} For this reason the first program outlining instrument development called for construction of instruments which would measure engine torque and rpm, propeller thrust, airspeed, angle of attack, and inclination of the wing chord.\textsuperscript{39}

Almost immediately after the opening of the laboratory, a section was established for the research

\textsuperscript{36} Interview with F. H. Norton.


\textsuperscript{38} \textit{NACA 7th Annual Report, 1921}, 32.

\textsuperscript{39} H. A. Soulé, "Notes on Flight Research," August 4, 1948, NHA.
and development of new recording instruments. The work of this section was directed by Fred H. Norton and included such others as H. J. E. Reid, later laboratory director, and Pearl I. Young, subsequently noted for the refinement of technical editing at Langley.\textsuperscript{40}

Among the instruments necessary to begin the flight researches was an accelerometer to provide a measurement of the loads on an airplane during its landing and maneuvers. In addition, manometers were available for obtaining pressure distribution on the airplane, but only during steady flight.\textsuperscript{41} Requests for other instruments were received as the need arose for further scientific investigation of the phenomena of flight. Increasing sophistication in research techniques led to the desire for additional information, thereby necessitating new methods of acquiring the data.

Instrumentation development was also important in conjunction with later advances in wind tunnel technology. As new tunnels were constructed, often new instruments had to be produced for tunnel measurements. Many times this proved as difficult as providing instruments for aircraft tested in free flight: differences

\textsuperscript{40} Interviews with F. H. Norton, H. J. E. Reid, and Pearl I. Young.

in scale effects in tunnel-tested models had to be taken into account. In both development of balances for the tunnels and equipment to record the results, Langley engineers created new devices which previously would have had no utility. 42

One of the circumstances accounting for the success of the instrumentation section was the availability of a nearby flying field to test the new equipment. If an instrument did not perform as well as had been expected, immediate modification would be implemented and a re-test carried out with little delay. For instance, in 1931, it was discovered that an airtight case to cover an instrument would give a more accurate reading and the machine shop workers immediately began attacking the problem. 43

The instrumentation section itself was unique in the organizational structure of the Langley Laboratory. Apart from the administrators, only this section had

42. Interviews with David L. Bacon, October 3, 1967; and Fred E. Weick, October 2, 1967. Also see Chapter V.

43. U. S. House, Committee on Interstate and Foreign Commerce, Hearings Before the President's Aircraft Board, 69th Cong., 1st Sess., 1925, I, 343; New York Times, May 17, 1931, IX, 10. Not until March 27, 1926, did the instrumentation section, important as it was, have a building of its own at Langley. "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943, 2.
direct access to all other divisions of the laboratory. When a problem arose which required a new instrument or an improvement of an already existing one, often the head of the instrumentation section would assign an engineer to work with the requesting division "to build exactly what they needed." Indeed the organizational structure was so loose in the 1920's--probably as a consequence of the fact that the number of employees did not reach 200 during the decade--that when a new measurement problem arose, the researcher could call a friend in the instrument section, explain what type of result he wished to achieve, and ask if such an instrument could be constructed. There was no need, as later was the case, to submit formal requests. Due to this close cooperation, slight adjustments could be made as the instrument was being developed.

Henry J. E. Reid, later Engineer-in-Charge of LMAL, is generally credited with the most important successes in instrumentation research. He either designed


46. Interview with Harold I. Johnson.

47. Interviews with H. J. E. Reid and R. E. Mixson.
or worked on improvements for such basic flight research tools as the airspeed recorder, accelerometer, recording altimeter and angular velocity recorder. Reid did not claim credit for the projects he worked on, but his important role cannot be discounted. Another important figure was Fred H. Norton whose primary contribution was the multiple manometer. Norton led the instrumentation research at a time when almost all work was on a "hit-and-miss" basis. More sophisticated tools were an absolute necessity for the creation of a scientific body of information concerning the dynamics of flight.  

There is little doubt that the accomplished instrumentation research formed the foundation for all other experimentation at the Langley Laboratory. Without the measuring tools, the function which the laboratory, and indeed the NACA, hoped to serve, would have been quite impossible.

Primary among the instruments developed at Langley in the early 1920's was the multiple manometer. Its purpose was to measure with precision the pressure distribution over the wings of an airplane in free

flight. In 1920, pressure distribution tests had been made over the horizontal tail surfaces on a JN4H airplane at the request of the Navy's Bureau of Construction and Repair. This was accomplished by use of the only manometer then available, a liquid-in-glass type, and a camera which automatically photographed the readings to obtain simultaneous recordings of the pressures on 110 orifices to which the manometers were connected. By using liquid manometers, tests could only be made in steady flight, and the results showed that the pressures "could not in any conceivable way cause failure, even on the weakest tail plane."

Since the liquid manometer proved generally unsuitable to anything except steady flight, a new non-liquid instrument had to be devised to gain more complete information on dynamic flight pressures. Fred

49. The determination of accurate airspeed measurements was accomplished by exact measuring of a land course and mathematically determining speed by elapsed time flying between two land points. Interview with F. H. Norton (who assisted in laying out the course).


Norton went to work on a recording multiple manometer to be utilized in determining the pressures on wings during accelerated flight. Further, the instrument was constructed so that a pilot could start and stop the recording mechanism with a single switch.

Using the knowledge available on the flow of air over a wing and distribution of load over an airplane during accelerated flight (this knowledge was extremely limited), Norton designed a multiple manometer. Through connecting tubes lining the inside of the wing and tail and attached to tiny openings thereon, this instrument could make simultaneous readings in any type of flight. 53

The manometer itself consisted of small diaphragm gauges which continuously recorded on film the data concerning the rise and fall of pressures at various points. This information had been requested by the engineering division of the Army Air Service in order to aid them in recommending design changes on the aircraft being built for military service. With the multiple manometer, pressures over the entire wing could be measured, thereby giving a more complete bank of data.

than had ever previously been available. The results of the Langley free flight tests pointed out the errors of the designers in determining, albeit unscientifically, the degree of air pressures over various portions of the wings of airplanes they had engineered.  

The innovations in manometer design were not, of course, the only developments in instrumentation in the 1920's at Langley. For accuracy in determining velocity, a new air speed meter was invented in 1922 to provide an exact measure of airspeed. This meter was combined shortly afterward with an altitude recorder by connecting an airspeed capsule and a barometric cell, which produced a continuous trace on film. An electrically operated multiple camera device took continual pictures of the recording dials to alleviate the possibility of incorrect human reading of the acquired information. To correspond with the readings of airspeed and altitude, a "control position recorder" was built and


then tested by NACA test pilot Tom Carroll. This device indicated the "exact position of all the controls during any maneuver or part of a flight." By 1925, the NACA had developed instruments by which they claimed to be able to "obtain a continuous record of the forces and of all the properties of an airplane when it is going through any kind of maneuver." A later combination of instruments added a galvanometer to the airspeed meter and the barometer, thereby facilitating measurement of temperature gradations along with other readings.

Coincidental to the refinements of the instruments themselves was the increased employment of photographic techniques for retaining a complete record of any flight. Guesswork by the pilot concerning conditions during a flight was precluded by a film which told the exact

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56. Much praise was given the test pilots in almost all interviews conducted by the author. These men often flew under conditions considerably lacking in safety. They were a courageous group and cannot be discounted in the overall success of research at the Langley Laboratory.


events as they had taken place. The motion picture camera developed to perform this function was originally demonstrated by Dr. Joseph S. Ames, NACA Executive Committee Chairman, at the industry conference held at Langley in the spring of 1930. It had taken most of the first decade of research at the laboratory to evolve this technique to anything near "perfection."

One instrument utilized was the "automatic observer," a camera which photographed conventional indicators on the aircraft. The altimeter, tachometer, and oil pressure indicator were viewed in this manner throughout the duration of a flight. A photographic record was achieved by the instrument activating a stylus which in turn moved a mirror causing a beam of light to move along the camera's film. This could produce an accurate record as the beam of light "has no inertia and is not affected by the speed or violent maneuvering of the plane." Each development in instrumentation


generally coincided with a commensurate advance in the
technique of retaining an exact record of the readings
taken.

One of the most baffling problems facing aeronautical engineers was that of measuring gust load
factors on an aircraft; that is, the reaction of an
airplane when struck by a sudden turbulence. This need
was recognized by the NACA in the late 1920's when
measurements were being made with a NACA-modified
instrument commercially available as a Tetco TIM
recorder.63 The LMAL conversion of this instrument
registered "accelerations of the machine normal to the
plane of the wings." Because this instrument did not
measure angle of attack but only airspeed, not enough
information as was desired, could be gathered. Eugene E.
Lundquist, Langley engineer, pointed out the need for
this information in charts of the acceleration and the
airspeed tests of the U. S. Navy's first dive bomber,
the XBN-1.64

Furthermore, the NACA accelerometers and airspeed
recorders, which had been used to gather data, were
delicate and required more maintenance than time allowed.

64. Ibid.
Therefore, Richard V. Rhode, a Wisconsin-trained mechanical engineer, suggested that one instrument be constructed which could: (1) measure both acceleration and airspeed in rough air for conversion to "effective gust velocities," by going through the process Lundquist had developed; (2) take measurements over a long period of time; and (3) be simple enough and sturdy enough to require minimal attention and repair. 65

Henry J. E. Reid, by then Engineer-in-Charge of the Laboratory, became interested in producing the instrument and, using Rhode's ideas, began experimenting during his leisure time in the instrumentation laboratory. His interest in the project led him to doing this work on Saturdays when administrative duties were not pressing. The device Reid invented employed a flexible steel stylus which would record the information by scratching a line on a smoked-glass plate. From this, the applied load factors and corresponding airspeeds could be measured—this is part of the reason the name VG Recorder was given the instrument: V is the standard symbol for airspeed and G the abbreviation for acceleration of gravity. 66


Reid was interested, once the recorder had been built, in insuring that it could not be destroyed regardless of what happened to the aircraft carrying it. He requested the machine shop at Langley to make a "destruction-proof" enclosure for the instrument. When the first casing was brought to Reid, he lifted it above his head and slammed it to the floor with all his strength. Seeing the casing smash apart, Reid calmly said to the machinists, "No, that's not quite strong enough," whereupon a considerably stronger casing was built.\(^{67}\) This "trial-and-error" methodology was perfectly in character with experimentation at the laboratory.

The VG Recorder was placed on many commercial and military aircraft and, by 1940, had recorded over 100,000 hours of flight time. The military credited the recorder with often furnishing "the keystone for the correct analysis of the failure or damage to an airplane in flight." A later adaptation, the GA Recorder complemented the VG Recorder by adding variation of gusts with altitude readings to the measurements previously gathered.\(^{68}\)

\(^{67}\) Interview With H. J. E. Reid.

\(^{68}\) Ibid.; NACA 26th Annual Report, 1940, 9; Frank M. Kennedy to J. S. Ames, July 16, 1937, LaRC Files.
To conduct tests of the instruments, the Langley Laboratory, during its early years, used mostly borrowed airplanes. A complete range of free flight tests were made with these airplanes. The NACA budget was too small, never going above a million dollars until 1930, to allow enough funds for purchases of airplanes. The NACA acquired its first "borrowed" airplanes in early 1919 by borrowing two JN4H "Jennys" from the Army. The research with these Jennys, beginning with the first NACA flight at Langley on March 2, 1919, was an attempt to measure drag and performance of the airplanes at various altitudes.69 Further tests with these two airplanes were carried out in the summer of 1919, gathering data in free flight to compare with results to be obtained in the Atmospheric Wind Tunnel being constructed at that time.70

The original flight test piloting was done by Army Lieutenants Eddie Allen and H. M. Cronk (the NACA also borrowed pilots!). Allen was later in charge of


aeronautical research for the Boeing Company.  

Soon Tom Carroll, World War I fighter pilot, and Paul King, son of Utah Senator William H. King, were hired as permanent test pilots for the NACA. The Langley test pilots not only did the flying assigned to them, but also developed many ideas for free flight testing on their own. For example, Tom Carroll developed a technical report on his own investigations of take-off and landing procedures. This, like many other Langley-produced reports, was designed to increase the safety of flying.

Following acquisition of the two Jennys, the laboratory soon borrowed many other planes in order to conduct experiments. By 1921, five airplanes had been borrowed, and another six were received in 1922. The airplanes were loaned to the NACA by both the Army and Navy aviation sections. Often these were obsolete

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74. These aircraft were three JN4H's and one each of a VE-7, S.E. 5, DH-4, Thomas Morse MB-3, Spad 7, Nieuport 23, Fokker D-7, and DH-9. NACA 8th Annual Report, 1922, 11.

75. Interview with Walter S. Diehl.
aeroplane, but the engineers at Langley were grateful for any aircraft they could acquire. Often these aeroplanes were used for non-research activities. The NACA Annual Report for 1922 admitted that only "forty-six per cent of the flying time has been confined to actually making measurement in the air." 76

The first accident during flight testing at Langley took place in 1924. A young engineer, Stephen Bromley, in his first observation flight, was killed in an aeroplane flown by Smith J. DeFrance. DeFrance, later Director of the Ames Laboratory, was seriously injured and, although recovering fully, never flew again in any type of aircraft. 77 Due to the Langley safety procedures instituted, no other person was killed during a test from that time until the 1950's.

In late 1924, the NACA decided to purchase an aeroplane for its research purposes. George W. Lewis,

76. NACA 7th Annual Report, 1921, 32; NACA 8th Annual Report, 1922, 11; F. H. Norton, "Flight Work Now Being Carried on by the National Advisory Committee for Aeronautics at Langley Field," Aeronautical Digest, 2 (February, 1923), 84-85. In the rather informal atmosphere of the laboratory, many times young ladies were taken for aeroplane rides after passing a "flying adaptability examination," which usually consisted of being spun around in an office chair. Story told to the author in confidence.

NACA Director of Aeronautical Research, testified that the purchase was necessary because the Army and Navy "had none of the type and construction needed." The airplane was built especially for the NACA so that the laboratory engineers "could make a complete pressure distribution investigation, and it had to be built stronger than the ordinary airplane." A second airplane was purchased because "it was very simple to make modification, such as the replacing of a wing." This made the craft extremely useful in flight testing varying shaped airfoils the NACA was examining.

Other aircraft purchased by the NACA were usually new types which the military had not yet required. When many aviation experts felt the autogiro would become useful, the NACA purchased one to "study the possibilities of this form of aircraft." LMAL tested the autogiro in its newly established Flight Research Laboratory.

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78. U. S. House, Independent Offices Subcommittee, Hearings, 68th Cong., 2d Sess., 1925, 396. Coincidentally, the NACA requested an appropriation for the purchase of the airplane after the order for it had been placed.

79. Ibid., 71st Cong., 2d Sess., 1930, 277.

80. Ibid., 72d Cong., 1st Sess., 1932, 304; NACA 17th Annual Report, 1931, 7; "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943. An autogiro
All repair or adaptation work on these aircraft, either borrowed or owned, was done by Langley-employed mechanics. In this way the laboratory personnel had a greater degree of control over what was being altered. The military, especially the Army Air Service installation at Langley Field, was very cooperative in providing spare parts needed for maintenance of the airplanes, and allowing Langley mechanics to use the Army's aircraft repair shop on the field. Thus began a long period of amicable relations between the NACA and Air Service personnel at Langley Field.

Cooperation continued while the staff at the Langley Laboratory grew from 11 employees in 1919 to 149 (of which only 45 were professionals) in 1927. Accompanying the growth in staff and investigations, the budget appropriations increased from $205,000 to $513,000 by 1927. However, events outside the direct

is an aircraft with rotating wings on which, unlike the helicopter, the air flows upwards through the disk rather than down.


82. Staff figures are in "Growth of Langley's Staff: Professional, Non-Professional and Total," June 30, 1959, NHA. Budgetary figures for NACA throughout its history are available in a booklet kept in the Budget Office of the NASA. See Appendices D and E for these figures.
purview of the NACA affected its development. Following the end of the war in Europe, the interest of the general public in aviation waned. American aviation strength during the war had been negligible and a peace-time America refused to consider the possibility of another war.

Among the public figures propagandizing for aerial defense was the illustrious Billy Mitchell. Mitchell wrote and spoke, almost continually, on the value of air power in national defense.83 His clarion call was listened to widely due to his fame as a pilot in the first war. His court martial in 1925, however, somewhat diminished his influence and his effect on aeronautical progress was minimal until his death in 1936.84

One group which assuredly did appreciate the value of research the NACA conducted was the growing aeronautical industry. The companies could appreciate

83. There are some who felt Mitchell did more to damage the cause of American aviation than to strengthen it. See the interviews between Alfred F. Hurley and John F. Victory, summer, 1962, NHA.

NACA's research: they did not have to establish their own laboratory facilities. Some doubt exists, moreover, that industry during the 1920's had the financial resources to develop laboratories if it had been necessary.85 Despite this, the growth of the industry undoubtedly gave it added influence in Congress. Aviation companies were generally willing to give the NACA, and thereby the Langley Laboratory, as much assistance as possible.86

Certainly the most important boost to American aviation in the 1920's--probably the most influential event since the flight of the Wright brothers--took place on May 20, 1927. On that misty morning at 7:32 AM Charles A. Lindbergh took off in The Spirit of St. Louis for a flight that captured the imagination of the world. This first solo flight from New York to Paris, and the excitement it created, gave as much of an indirect thrust to the NACA as any event could. Aviation news and research developments could now command the interest of a much wider segment of the population.87

85. Interview with Grover C. Loening.
Of equal importance, but considerably lesser public note, were technological advancements being made at the Langley Laboratory. This research had begun in the early 1920's and was carried out through the entire history of the institution. A majority of these developments can be attributed to the sophistication of model-testing in the Langley wind tunnels. The laboratory made tremendous innovations both in type and utilization of wind tunnel techniques.
CHAPTER V

WIND TUNNEL TECHNOLOGY, 1920-1939

Few research tools employed in the study and advancing technology of the phenomena of flight have proved as significant as the wind tunnel. Alterations in design often required free-flight testing, not always practical, because of possible danger to the test pilot, when major changes were contemplated. Moreover, tests are generally conducted more inexpensively by placing a model in a wind tunnel rather than building and equipping a full-size airplane for free-flight testing.¹ This economy factor, especially in a governmental organization, inherently plays an important role.

In general two types of tunnels are used. The open-circuit, or Eiffel type, contains no passage for air to return for reuse through the tunnel. This type of tunnel draws air directly from the atmosphere. In a closed-circuit, or Prandtl tunnel, a return flow section is constructed to form a continuous path for the air, allowing its reuse. Because the closed-circuit wind tunnel makes more efficient use of its available energy, the open-circuit method, although cheaper to construct,

¹ Max M. Munk, The Principles of Aerodynamics (Washington: by the author, 1933), 214
is seldom utilized. The type and construction of the wind tunnels erected at the Langley Memorial Aeronautical Laboratory were determined primarily by the method of testing they were to accomplish. A tunnel, once it was completed, was not a static tool; innovations were made as the state of the art evolved.

Nobody supposed that the wind tunnels could answer all aerodynamic questions raised. Edward P. Warner, former Langley Chief Physicist, attested to this, saying there was "no single standard by which all airplanes could be tested. Wind tunnel tests must be used with proper regard to the models used," Warner said, "and proper interpretations must be given to the results." Agreements with European governments permitted a comparison of wind tunnel results to determine how much discrepancy existed when testing the same model in various tunnels. Many models were tested not only at Langley, but also in wind tunnels at both the British and French aerodynamical research centers.


Comparisons were also necessary between results achieved in wind tunnel investigations and instrument readings acquired during free flight. This relationship was first studied at Langley in 1921 by towing wings and other objects under an airplane in flight and comparing the data with wind tunnel results of model tests. In addition, the early wind tunnels offered information only for performance in unaccelerated flight, and therefore could only "give an indication of the possibilities of the airplane," or portions thereof being investigated. The leadership at LMAL was not blind to the inherent difficulties in the use of this tool and each new wind tunnel heightened chances for greater reproduction of actual flight conditions without leaving the ground.

The first NACA plans for construction of a research laboratory were paralleled by designs for a five foot atmospheric wind tunnel to be erected on the site.


7. Preparation of plans and specifications was authorized in late 1917, and the plans were approved by the NACA in April, 1918. NACA Executive Committee Minutes, November 15, 1917, April 29, 1918.
Because of staff size and other limitations, the NACA decided that its first wind tunnel should be basically a copy of those already existing in Europe. This emulation, it was hoped, would give the laboratory a relatively successful start, as using knowledge of tunnel construction already gained by European aerodynamicists would assuredly create few unforeseen problems.

Erection of the building housing this first tunnel and, indeed, many parts of the tunnel itself were assigned to Army personnel. The building was of brick and concrete, with the latter providing a solid foundation to prevent any unbalance of the propeller or motor of the tunnel which would cause vibrations to upset the accuracy of measuring instruments. Because the tunnel was of the open-circuit type, doors were designed to prevent distortion of the tests by exterior winds.

Prior to construction of the tunnel, a working model was produced and tested to insure satisfactory results with the full size apparatus. The tunnel was built within a chamber, ten feet long, fourteen feet wide.


9. See Chapter III.

and twenty-three feet high; the working section, where models were tested, had a diameter of five feet. Four concrete columns supported the chamber; this strength was able to withstand the heavy pressures which occurred during high-speed operation of the tunnel. For inspection of a test, "three curved glass windows [sat] flush with the inner surface of the tunnel, two in the floor of the tunnel and one in the top."\textsuperscript{11} Energy to run the tunnel was provided by a 200-horsepower variable-speed motor. Before electrical connections were completed, a dynamo driven by a Liberty engine temporarily produced the power to run the motor. The power plant allowed testing at speeds up to about 120 miles per hour.\textsuperscript{12}

In the design of a balance\textsuperscript{13} for the tunnel, the type in use at the National Physical Laboratory of England was duplicated. The only modification of the N.P.L. balance was made to allow the measurement of larger forces, as it was felt that the English balance would not "prove applicable to tunnel sizes and wind

\textsuperscript{11} Ibid., 489-90.

\textsuperscript{12} Ibid. A Liberty engine was one of those originally built for American airplanes during World War I.

\textsuperscript{13} A balance is the device on which a model rests during testing. Various connections allow readings of the forces acting on a wind tunnel model undergoing examination.
speeds very much in excess of those at present realized."\textsuperscript{14} To accomplish this, a ball bearing socket, rather than a conical pivot, supported the weight of the model being tested. In this way the lift, drag and pitching moment could be measured simultaneously.\textsuperscript{15} David L. Bacon, working with the men in the LMAL shop where the balance was constructed, devised a method of preventing model vibration during testing, while still allowing accurate readings. This was accomplished by a series of wires connecting the model and the tunnel walls.

The completed tunnel was opened during dedication ceremonies in June, 1920, although it was not officially accepted from the Army Constructing Quartermaster until July 16, 1920.\textsuperscript{17} During the first few months of operation while the tunnel was calibrated and checked for accuracy little actual testing was conducted. Tests were also conducted in the atmospheric wind tunnel to be compared

\begin{itemize}
\item \textsuperscript{15} \textit{NACA 6th Annual Report}, 1920, 24.
\item \textsuperscript{16} Norton, \textit{S. A. E. Journal}, 8 (May, 1921), 491-92.
\item \textsuperscript{17} "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943, NASA Historical Archives (NHA), 1. (Hereafter cited as "Wind Tunnels at LMAL.")
\end{itemize}
with like tests in other tunnels throughout the world. Elliott G. Reid of Langley, who supervised many of these tests, said however, that because of differences inherent in the tunnels, "standardization constants were not yet possible." 18

A 1/24 scale model of a JN4H biplane was the first object of research in the LMAL's first wind tunnel. To correct for lack of a slip stream effect (air stream created by a propeller) in the tunnel testing, a small belt-driven propeller was mounted in front of the model and driven by an electric motor above the tunnel. For more accuracy in the tests of airfoils and pressure distribution over models, a honeycomb was installed in the front of the tunnel to improve the quality of the air flow. 19

Important as the atmospheric wind tunnel was for providing a successful beginning to the tunnel research at LMAL, it was of limited value and was replaced in 1929 by two tunnels: a five foot vertical tunnel and a 18. E. G. Reid, "Standardization Tests of N.A.C.A. No. 1 Wind Tunnel," Technical Report No. 195, NACA 10th Annual Report, 1924, 219.

seven by ten foot, rectangular throat tunnel. The latter was equipped with a six-component balance which could measure "three forces and three moments directly and independently." The atmospheric wind tunnel had served its purpose and following it, more original concepts and designs of wind tunnels evolved at the Langley Laboratory.

Shortly after completion of the atmospheric wind tunnel, plans were formulated for Langley's first major innovation in wind tunnel technology. The greatest need in aerodynamical research was a wind tunnel which could more closely approximate actual flight conditions. Because of scale effect, models tested in wind tunnels did not give results which were readily adaptable to full size aircraft. A device was needed which would increase the air density in which the tests were conducted so that the Reynolds number of the model was equal to that

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21. In most common terms, the difference between results acquired from tests on a model and the same results achieved by building a full-size piece of equipment. See R. C. Pankhurst and D. W. Holder, Wind-Tunnel Technique (London: Sir Isaac Pitman and Sons, Ltd., 1952), 8.

22. An object's response to airflow is dependent on its size, speed at which it moves through the air, density of the air and viscosity (stickiness) of the air. The multiple of the first three divided by the
of the full size aircraft. This could be accomplished by pressurizing a complete, closed-return wind tunnel.

Langley's premier theoretician, Max M. Munk, a German-trained aerodynamicist, first conceived a variable density tunnel in 1920, although the same idea had been formulated some years earlier. Munk felt it was possible to reproduce "not only the model, but the entire...[air]...flow" in a wind tunnel to duplicate the ratio occurring in full scale flight. The atmospheric wind tunnels which were in general use, Munk contended, made model tests "at a Reynolds number smaller than in free flight." Joseph S. Ames, NACA Executive Committee Chairman, had thought that the second tunnel to be built at Langley would be simply a larger atmospheric type. However,

fourth produces a scale index called a Reynolds number. See George W. Gray, Frontiers of Flight (New York: Alfred A. Knopf, 1945), 35. Munk, Principles of Aerodynamics, 31-35, is more difficult for laymen to comprehend.

23. Munk had received a doctorate in philosophy and in engineering before coming to the United States about 1919. Interview with Walter S. Diehl, September 12, 1967.


25. Ibid., 409.

when Munk suggested in 1921 the construction of a variable density tunnel, Ames immediately recognized the value of this facility and submitted the plan to the NACA Executive Committee which approved the project on June 9, 1921. National pride among those interested in aeronautics brought praise to Dr. Munk for planning a tunnel which was "of original design, not copied from any European example." Once the concept and construction had been authorized by NACA Headquarters, Munk, Elton W. Miller, and David L. Bacon, all LMAL staff members, began working on plans for the mechanical features of the tunnel. Basically, the concept was implemented by placing a wind tunnel of five feet diameter within a steel tank fifteen feet in diameter and thirty-four feet long. Air pressure, up to twenty atmospheres, would be built up by


28. Overlooked, of course, was the fact that Munk was European-trained. "Wind Tunnel Testing," Aviation and Aircraft Journal, XI (August 8, 1921), 159.

compressing it within the tunnel in order to make a representative test on a model.

The Newport News, Virginia, Shipbuilding and Dry Dock Company was assigned the duty of constructing the tank. It was made of lapped steel plates which were jointed together in the fashion of a steam boiler. When built, the tank was strong enough to withstand an internal pressure of 450 pounds per square inch, although it was expected that the tank would be used at an average working pressure of only 300 pounds per square inch. 30

Preliminary work on Langley's variable density wind tunnel began in July, 1921, and the initial performance of the completed structure took place on October 19, 1922. 31 To attain the desired pressure within the tank, air was compressed in two or three stages depending on the desired final pressure. In addition to being able to make tests at ranges up to twenty atmospheres, Langley engineers, by pumping air out of the tunnel, could also experiment at pressures as little as 1/12 of an atmosphere. This range, and its adaptability to full-scale flight, led Dr. Ames to declare that with the existence of the


31. The tunnel was built at a cost of $262,499.29 (quite expensive at 1922 standards). "Wind Tunnels at LMAL," November 15, 1943, 2.
so-called VDT, the laboratory engineers had "more important information in regard to the strength of airplanes than any other engineers in the world." 32

Following calibration tests of the tunnel, a preliminary examination of wing models was conducted in the VDT. Since testing in the atmospheric tunnel had proven unsatisfactory for this purpose, Munk and his associates at Langley hoped, through these model tests, to determine if Reynolds number was indeed the most essential factor in investigating air forces on wing sections. A series of eighteen tests were made and results calculated to determine lift and drag of the various sections. Discovery of the relative importance of Reynolds number and lack of a significant variation due to roughness of surface and sharpness of trailing edge were the most important results gleaned from this first series of wing-section investigations. The researchers were so pleased with the general accuracy of the results achieved that they felt that "tests with a systematic series of different wing sections...[would]... bring consistent results, important and highly useful for the designer." These results eventually allowed Langley

engineers to analytically design and test the entire
series of NACA wing sections.  

Shortly afterwards, a full research program was
instituted in the VDT. In the fall of 1924, a turbulence
factor created by the tunnel walls was discovered and
data was adjusted to take the turbulence into account. Despite this fault, the British Aeronautical Research
Committee was so impressed by the capabilities of the
VDT that they sent many of their models to Langley for
testing to compare with results they had acquired in
flight. The results of the VDT tests of these models
were so accurate that the British were convinced of the
necessity of building their own tunnel based on the
Langley structure.

33. Max M. Munk, "Preliminary Wing Model Tests
in the Variable Density Tunnel of the National Advisory
Committee for Aeronautics," Technical Report No. 217,

34. E. N. Jacobs and R. F. Anderson, "Large-
Scale Aerodynamic Characteristics of Airfoils as Tested

35. Eastman N. Jacobs, "Work in the Variable
Density Tunnel of the N.A.C.A.," Aviation, XXIII
(September 12, 1927), 620-23; U. S. House, Independent
Offices Subcommittee, Hearings, 70th Cong., 1st Sess.,
1928, 287. Because of the turbulence factor the
systematic testing of airfoils was repeated in 1945.
See I. H. Abbott, A. E. von Doenhoff, and L. S. Silver,
The variable density tunnel, as originally built, had a rather short history of operation due to a near disaster. On August 1, 1927, during a test of an airplane model at twenty atmospheres, an electric-light bulb burst under the pressure. A short circuit resulted which in turn caused an arcing which set off a fire within the interior of the tank. Although all systems were immediately shut off, the internal pressure of 300 pounds per square inch led to rapid spreading of the flames. Subsequently the entire structure of the VDT had to be disassembled and rebuilt at a cost of $20,000; albeit with fireproof materials.36 Following the reconstruction, the VDT played an essential role in Langley airfoil research until its replacement in 1939 by a nineteen-foot pressure tunnel in which much larger models could be tested.

Judging from the innovations attendant upon its use, one of the most important tunnels developed at the Langley Laboratory was the Propeller Research Tunnel (PRT). Prior to the building of this tunnel at LMAL, most of the propeller research conducted in the United States was performed by Drs. W. F. Durand and E. P. Lesley at

Stanford University under contract with the NACA. Some propeller testing was also carried on by the Air Service at McCook Field, Ohio. Another man, working on propeller design for the Bureau of Aeronautics of the Navy, was most important in planning for the PRT at Langley. This engineer, Fred E. Weick, later came to work at Langley to direct research conducted in the PRT. While working for the Bureau of Aeronautics, Weick had many opportunities for conversation with George W. Lewis of the NACA, whose offices were in the same building. During one of these discussions, Weick suggested that a more effective manner of measuring thrust and torque of a propeller would be in full-scale testing.

Lewis, during one of his frequent visits to Langley, broached the possibility of building such a

37, Reginald M. Cleveland, America Fledges Wings (New York: Pitman Publishing Corporation, 1942), 145. For many years Cleveland was the aviation editor of the New York Times and strongly supported NACA expansion and research projects. Interview with Robert E. Mixson, January 11, 1967.

38. See the testimony of Major General Mason M. Patrick in U. S. House, Select Committee of Inquiry into Operations of the United States Air Services, Hearings, 68th Cong., 1925, II, 568-69.

39. Interview with Fred E. Weick, October 2, 1967. The author would like to thank Mr. Weick, of Vero Beach, Florida, for an extremely illustrative and valuable interview on this and other features of the Langley history.
wind tunnel with the laboratory's "resident theoretician," Dr. Max M. Munk. When Lewis told Weick that Dr. Munk agreed it could and should be built, Weick was stunned: "The largest wind tunnel we had was a five foot wind tunnel at that time," and the proposed PRT was to have a twenty-foot throat. Lewis said it was possible and offered Weick a job running the tunnel once it was completed.40

The plan was proposed to the NACA Executive Committee which in June, 1925, authorized construction of the tunnel.41 As designed, the tunnel was large enough to test full-scale aircraft propellers, and make aerodynamic tests on fuselages, landing gears, tail surfaces and other airplane parts. Further, model wings of up to a twenty-foot span could be tested in the PRT.42

When completed in 1927, the tunnel was a steel-frame, wood-walled structure 166 feet long and 89 feet

40. Ibid. See also, Munk, Principles of Aerodynamics, 221.
41. NACA Executive Committee Minutes, June 25, 1925. Some indication of how decision-making was conducted in the NACA is evidenced by the fact that prior to formal committee approval, preliminary work began on the tunnel April 28, 1925. "Wind Tunnels at LMAL," November 15, 1943, 2.
42. Because of results achieved with its use (see Chapter VII), the Propeller Research Tunnel seemed to become the "white-haired boy of the engineers." See W. B. Courtney, "There's Magic in the Air," Colliers, 98 (November 14, 1936), 56.
high. The throat of the tunnel was 20 feet and the experimental chamber 50 by 60 feet in length and breadth, and 50 feet high. It was designed as an open jet-type tunnel so that no correction for tunnel-wall interference would be necessary. Circulation of air was created by a twenty-eight foot diameter propeller with a velocity of approximately 100 miles per hour. Because the local power company in Hampton could not provide enough energy to drive the propeller, a "loan" was arranged with the Navy. The Navy Bureau of Aeronautics acquired two 1000-horsepower submarine engines which had been marked for disposal as obsolete, and gave them to the NACA. These provided the power source to create the airstream for the PRT. Navy Captain Walter S. Diehl, long-time friend and associate of NACA research, made the arrangements for this gift.

To make measurements in the tunnel, a balance was designed by Weick, who was now employed at Langley. The process by which this was accomplished was somewhat unusual. Normally a complete design would be drawn and


then the laboratory mechanics would build it. In this instance Weick, instead, drew sketches of portions of the balance on cross section sheets of paper and the instrument, after the approval of Dr. Munk, was constructed literally piece by piece. Only after the entire balance was finished was a complete drawing made by the Langley draftsmen—and then only for the laboratory's permanent records.

This first wind tunnel in the world in which the major parts of a full-size airplane could be investigated cost $394,978.12 to build. Considering the value of discoveries resulting from investigations employing the propeller research tunnel, the price was extremely reasonable. The NACA cowling, nacelle placement innovations and value of the retractable landing gear were all directly related to research in the PRT. Prior to World War II the tunnel proved to be one of Langley's most valuable assets.

After completion of the propeller research tunnel, the next logical step was the development of a tunnel in

45. Interview with F. E. Weick. Weick recalls that the entire structure was built for a cost, in addition to salaries, of about $5,000. Approximately ten years later, when a more sophisticated balance was desired, the cost ran between $50,000-$100,000.

46. "Wind Tunnels at LMAL," November 15, 1943. 2.
which a complete airplane could be tested. For Langley it was a project of greater size and expense than any previously contemplated. The safety features of such a piece of equipment were obvious: no longer would there be any doubt when a new aircraft design was taken on its maiden flight. If a radical design change was incorporated in an aircraft, its aerodynamic soundness could be tested without having to make an actual flight. Ground-based full scale testing would reveal many of the dangers prior to free flight by eliminating any need for correction produced by scale effect.\(^{47}\)

For these reasons, J. S. Ames wrote the Director of the Budget in early 1928, outlining the need for a full-scale wind tunnel. At the laboratory, Smith J. DeFrance, who had previously worked with the variable density tunnel, was selected by Engineer-in-Charge H. J. E. Reid and Elton W. Miller, Chief of the Aeronautical Research Division, to lead the team which would formulate plans for the full-scale tunnel.\(^{48}\) Because this was the first tunnel with "an elliptic throat and with two


\(^{48}\) NACA Executive Committee Minutes, January 24, 1928; Interviews with S. J. DeFrance, June 16, 1967; H. J. E. Reid, January 10, 1967; and E. W. Miller, February 8, 1967.
propellers mounted side by side," DeFrance and his associates decided to build a 1/5 scale model to study the air flow.

During the planning stage, much effort was expended in winning Congressional approval as the tunnel would cost almost a million dollars. An appropriation request was tendered in 1928 for $5,000 to be used in design work for the full-scale tunnel. This having been granted, the NACA asked for, and received on February 20, 1929, a two-year appropriation of $900,000 with which to construct the tunnel. A contract was signed with the J. A. Jones Construction Company in February, 1930, for construction of the tunnel. DeFrance oversaw all phases of the erection process, and later supervised its actual operation.


50. The tunnel in addition had a dual return which had never been used before and which many aerodynamicists, including Theodore Von Karman, thought was not feasible. The 1/5 scale model proved it could be done, and the model itself was later used for testing. Ibid. DeFrance's assistants included Clint Dearborn and Abe Silverstein. Interview with S. J. DeFrance.

51. The War Department also granted the NACA additional land on which to build the structure. NACA Executive Committee Minutes, March 22, 1929; NACA 15th Annual Report, 1929, 9; NACA 17th Annual Report, 1931, 11.

52. NACA 17th Annual Report, 1931, 11; Interview with S. J. DeFrance.
The tunnel was completed and dedicated on May 27, 1931, at the sixth annual industry inspection of the laboratory. Not all the funds appropriated were spent and the leftover money was turned back to the Treasury, indeed an unusual action on the part of a government agency. 53 Besides holding the cost to a minimum, the DeFrance-led team managed to have construction completed in less than two years, a major achievement for a project of this scope. 54

As shown to the 1931 visitors, the full-scale tunnel had a 30 by 60 foot open jet at the test section within an overall tunnel size of 434 feet in length, 222 feet in width and a maximum height of 97 feet. 55

Because the structural steel frame was outside the cement-asbestos sheets which formed the walls of the tunnel, one writer said it "looked as if it was built inside out." 56 The test section was large enough to handle a full-size airplane with a wing span up to 45 feet through a range of 25 degrees of angle of attack. Air

53. Interviews with Manley J. Hood, June 15, 1967; and S. J. DeFrance.
stream speed, powered by two propellers, each connected to a 4,000-horsepower motor, ranged from 30 to 115 miles per hour, with 24 intermediate speeds. An airplane, when being tested, was supported on the balance structure by struts "so that its thrust line...[was]...at the tunnel center line, 34 feet above the floor of the test chamber." Seven scales registered pressure on an airplane during a test, and with the push of a single button, each scale's reading was recorded. Although only steady flight could be studied, the tunnel was the only one in the world where lift and drag characteristics of a full-size airplane could be investigated.

Not all those interested in aeronautical research, however, agreed that the new LMAL full-scale tunnel was as valuable as the NACA had promised. Dr. Max M. Munk, no longer a Langley employee, felt that "giant wind tunnels may prove a good investment for certain special research work, but not for investigating real airplanes." He contended that it was cheaper and more reliable to take measurements of a full-size airplane in free flight. Also, one aviation journal, in the midst of a campaign denouncing the NACA, asserted that the money spent in


building the full-scale tunnel was wasted and, because of turbulence problems, the tunnel was unworkable.

Edward P. Warner, editor of *Aviation* and former LMAL employee, and George W. Lewis, NACA Director of Aeronautical Research, each in turn answered the criticism. In a radio address Warner asserted that the building of the Langley full-scale wind tunnel was one of the most important steps ever taken in improving airplane designs. In the full-scale tunnel, Warner claimed, "minor changes can be made and the results determined to a fraction of a per cent within a few minutes. That represents the last word in scientific equipment for study of the airplane." Lewis, in testimony before the House Independent Offices Subcommittee, said that this tunnel would allow "all the forces acting on the plane...[to be]...accurately determined," as the tunnel could almost completely "simulate flying conditions." After discovering a turbulence problem, Eugene Lundquist, an

59. See "Page Mr. Byrns!" *Aero Digest*, 20 (February, 1932), 32; and Frank A. Tichenor, "Take Politics Out of Research," *Aero Digest*, 20 (March, 1932), 30, 86-88.


LMAL civil engineer, strengthened the tunnel's beams and overcame the slight vibration. 62

Over the years, the full-scale wind tunnel proved as important as any aeronautical tool at LMAL. Its greatest value, however, was realized during the period of World War II. As will be shown, investigations in the full-scale tunnel between 1938 and 1945 played a key role in the aerial defense of the United States.

Another problem which the NACA felt was adaptable to wind tunnel research was that of airplane spinning. Those engineers most concerned with measurements of stability and control desired to have some tool with which to determine the ability of various aircraft to recover from a spin. Furthermore, research on spin recovery was an absolute necessity to the armed forces as aerial military maneuvers often required a deliberate spin. 63

Earliest experimentation at LMAL on spinning problems was conducted in 1926 in a somewhat crude manner. Following preliminary tests in the atmospheric wind tunnel, a model made of balsa wood was dropped from the ceiling of an airship hangar. The reaction of the model

62. Interview with S. J. DeFrance.

63. Munk, Principles of Aerodynamics, 184; Gray, Frontiers of Flight, 50.
passing through this still air was noted and Dr. Ames claimed that from these tests the laboratory engineers had "been able to determine the factors causing failure to recover from a flat spin." 64

Contradicting these early claims, however, was a later admission that spin characteristics remained the "most important general problem now under investigation." 65 Obviously a new research tool was needed to conduct research in a more scientific manner. By the later 1920's, the five-foot atmospheric wind tunnel had lost much of its value due to increasing sophistication in tunnel technology, so the NACA decided to convert the AWT into a vertical tunnel. 66 This adaptation was completed in 1930.

64. NACA 12th Annual Report, 1926, 18. When the models were dropped from an approximate height of 70 feet, "a big clock dial was painted on the floor with a hand moving around it at a certain rate, and we photographed the spinning model from above. In this way, we determine exactly how fast the model spins and can study airplane characteristics that affect the spin." U. S. House, Independent Offices Subcommittee, Hearings, 69th Cong., 2d Sess., 1927, 293. See also H. A. Soulé and N. F. Scudder, "A Method of Flight Measurement of Spins," Technical Report No. 377, NACA 17th Annual Report, 1931, 267-82.


66. The original job order for the new design was issued June 28, 1928. A model was constructed first, and final plans for the full scale vertical tunnel completed in May, 1929. H. J. E. Reid to NACA, February 18, 1932, LaRC Files; NACA Executive Committee Minutes, September 25, 1930.
The vertical tunnel had an open throat five feet in diameter. Its wind stream passed through the test section, then entered an exit cone and passed through guide vanes to a propeller. Using a return passage, the air was then guided past a honeycomb and finally through the entrance cone. By means of this route, an upward airspeed of 80 miles per hour could be achieved. Early tests in this tunnel showed that "an involuntary spin is practically impossible with airplanes which have the elevator control limited to prevent a stall."  

Although one newspaper reported that with the vertical tunnel "every force acting upon...[an airplane]...can be observed and measured," aerodynamic researchers at Langley were not yet satisfied that all available data had been gathered. Therefore Langley engineer Charles H. Zimmerman was assigned the task of designing and building a larger spin tunnel. Preliminary


68. NACA 17th Annual Report, 1931, 56.


70. Later the 5-foot vertical tunnel was converted to have a rectangular 4- by 6-foot closed throat. It was then used for studies involving two-dimensional flow. NACA 24th Annual Report, 1936, 265.
work on the tunnel was started May 25, 1933, and by
September, 1934, construction was completed. Following
slight alterations and calibration tests, the new
tunnel was operated for the first time on April 3, 1935.
Because the test section was 15 feet in diameter, model
tests conducted were more representative of actual flight
conditions.

Tests could be viewed from an observation plat­
form which surrounded the open cylinder. A propeller
drove an air stream upward at speeds up to 50 miles per
hour. At the base of the tunnel a net protected the
models from any serious damage. With the tunnel the
NACA hoped to "study the effect of variations in the
dimensional properties of the airplane upon its spinning
characteristics." 72

During tests in this tunnel, with the air blowing
vertically upward, the model was tossed in with its
controls set to cause a spin. Following preliminary
observation of the spin, controls were reset to a position
to produce recovery although recovery from the spin was

71. NACA Executive Committee Minutes, October 18,
1934; C. H. Zimmerman, "Preliminary Tests in the N.A.C.A.
Free-Spinning Wind Tunnel," Technical Report No. 557,
NACA 22nd Annual Report, 1936, 265.

72. "Spinning Tunnel," Time, XXV (June 3, 1935),
55; Nayler and Ower, Aviation: Its Technical Development,
268-69; NACA 20th Annual Report, 1934, 10.
not always accomplished. During the time the model was freely flying, motion picture cameras recorded the entire progress of the flight. From the pictures, Langley engineers determined the angle of attack, angle of bank, revolutions per second and number of turns for recovery, thereby measuring the controllability of the vehicle. Calculations based on tunnel speed gave the rate of vertical descent. Adjustments could be made in the balsa wood model prior to testing in an attempt to determine which characteristics on the airplane were most crucial to spin recovery.

Although the 15-foot spin tunnel at LMAL was similar to the spin tunnel built by the British in 1931, it was—as with most tunnels at Langley—the only one of its kind in the United States. Tests in this Langley tunnel brought to aerodynamics the realization that tail construction was essential in spin recovery. Both in the saving of money, and, more importantly, lives, the spin tunnels at LMAL were well worth the expenditure allotted to build them.


74. NACA 20th Annual Report, 1934, 10; Naylor and Ower, Aviation: Its Technical Development, 268; Fortune, 23 (March, 1941), 144.
Aerodynamicists throughout the world realized the need for wind tunnels in which models could be tested at greater and greater velocities. As early as 1928, Langley leaders recognized the need and devised a method for inexpensively building a high-speed jet tunnel. The air in the variable density tunnel, once it had been compressed and used for testing, was discharged into the atmosphere. To utilize this "wasted" air, a new tunnel was constructed with an eleven-inch throat. In itself this was not innovative; however, compressed air from the VDT was piped to the high pressure chamber and "discharged through an annular nozzle." This created in the eleven-inch tunnel an air stream with an approximate speed of 800 miles per hour. Airfoil tests in this high-speed tunnel gave John Stack and other Langley engineers their first experience with a phenomena later called "compressibility," extremely important in studies leading to supersonic flight.

Despite the success of the eleven-inch tunnel, its small size severely limited its effectiveness. This problem was only slightly overcome with the construction

75. H. J. E. Reid to J. C. Hunsaker, August 4, 1948, LaRC Files.

of a second jet tunnel, with a 24-inch throat, in June, 1934. Although this tunnel did not yield any vital findings, it was important in the evolution of high-speed tunnel technology. By the mid-1930's, Russell G. Robinson of Langley had devised a method by which to build an 8-foot high-speed wind tunnel.\textsuperscript{77}

The NACA requested funds for this 8-foot high-speed tunnel from a source not previously utilized. With the inauguration of the New Deal and its multi-tudinous agencies, George W. Lewis, NACA Research Director, and the members of the NACA Executive Committee decided that justification of the structure as a "make-work" project might meet with success.\textsuperscript{78} On December 12, 1933, therefore, Dr. J. S. Ames, NACA Chairman, wrote the Federal Emergency Administration of Public Works (PWA) outlining the need for a wind tunnel, at an estimated cost of $478,300, capable of producing air speeds up to 500 miles per hour.\textsuperscript{79} The PWA Administrator, Secretary of the Interior Harold I. Ickes, following study of the worth of the project, agreed to finance it

\textsuperscript{77} NACA Executive Committee Minutes, October 18, 1934; NACA 21st Annual Report, 1935, 2; R. G. Robinson to author, December 28, 1967.

\textsuperscript{78} Interview with Smith J. DeFrance.

\textsuperscript{79} NACA Executive Committee Minutes, January 23, 1934.
on July 18, 1934. 80 This method of financing was quite helpful to expansion at LMAL during the depression era.

The tunnel was the subject of preliminary work in 1933, even before Langley had been assured funds to complete the project. 81 Upon completion, the tunnel was placed in operation on March 28, 1936. Use of a slotted-throat technique created in the 8-foot tunnel a continuous transonic flow—the first time this had ever been achieved in a wind tunnel. The tunnel had a minimum speed of 85 miles per hour and a maximum of 500 miles per hour. With a continuously controllable airflow speed, various models of aircraft and aircraft parts could be tested at extremely high speeds. 84 The tunnel formed an important link in the increased speed of flight, which later culminated in supersonic aircraft.


81. This was not unusual in Langley activities. Often background studies would be initiated in order to have a proposal ready when and if funds became available.


83. This was, basically, a series of longitudinal slots arranged at appropriate positions in the walls of the tunnel. Nayler and Ower, Aviation: Its Technical Development, 270.

An even larger high-speed tunnel (16-foot) was developed at Langley with the approach of World War II. Preliminary work on the 16-foot high-speed tunnel (500 mph) was started in February, 1939. It began operation on December 5, 1941, only two days before the Pearl Harbor attack.\(^{85}\) Total cost of the new tunnel, including structure and equipment, was $1,759,512.35,\(^{86}\) a far cry from the expense of some of the early Langley wind tunnels. This tunnel was built primarily for investigation of aerodynamic problems of military aircraft, at high Reynolds number and very high air speeds.\(^{87}\)

The various innovations in the realm of high-speed wind tunnels, although having significant individual results, all really provided a background to eventual development of supersonic aircraft. Without the steady progression of tunnel testing at greater velocities, the feats of 1947 would have been much delayed.

Prior to World War II, before a sufficient number of landing areas were available, interest in seaplane

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85. The 16-foot tunnel building was one of the first structures located in what later became the "West Area" of the Langley Laboratory. NACA Executive Committee Minutes, November 16, 1939, January 15, 1942.


87. Ibid. See also U.S. House, Independent Offices Subcommittee, Hearings, 78th Cong., 1st Sess., 1943, 139-40.
development was widespread. A Hydrodynamics Research Division was created at LMAL in 1929 under Starr Truscott and work was started on a towing basin (NACA Tank) to test seaplane floats for strength. 88 Research accomplished in this division was of great concern to the Navy's Bureau of Aeronautics. Throughout the 1920's and 30's the Navy felt that the seaplane would become an extremely important feature in Naval aeronautics, and it generally supported Langley investigation in this respect.

George W. Lewis, in 1929, recommended a plan for development of a seaplane channel to the NACA Executive Committee. Following approval of construction plans by the Committee, work on the so-called "NACA Tank" was inaugurated at LMAL on July 17, 1929, and completed May 27, 1931. 90 The towing basin, 2,020 feet long and 24 feet wide, was filled with approximately 4,000,000 gallons of water pumped in from the Back River, adjacent to the laboratory. Four 75-horsepower electric motors propelled the carriage which traversed the basin at speeds

88. H. J. E. Reid, Memo for Staff, October 12, 1929, LaRC Files; "Wind Tunnels at LMAL," November 15, 1943, 3.


up to 60 miles per hour. The model being tested could be towed through the water at constant speeds suspended from the tank-spanning carriage.

Research in the NACA Tank was primarily devoted to seaplane floats and flying-boat hulls. Measurements recorded included the towing pull, trim and rise of the model, moment required to hold the model at a fixed trim and strength of various structural materials. This tank, and the 1942 second tank and impact basin, all provided much information during that period in which American aviators felt the seaplane would have great commercial advantages. By the end of World War II, however, seaplane use began a decline from which it has never recovered, and research in hydrodynamics at LMAL has decreased proportionately.


92. Truscott, Technical Report No. 470, 537. The NACA later developed a wave suppressor so that waves produced in one test run were small enough not to affect the performance of a model in the next test run. NACA 20th Annual Report, 1934, 20.

93. Interviews with W. S. Diehl and J. B. Parkinson.
An interesting innovation developed on the heels of the free-spinning tunnel was the free-flight tunnel. Charles H. Zimmerman, designer of the spin tunnel, first suggested the concept in 1933, and approval for its construction was finally granted by the NACA Executive Committee in 1935, although preliminary work was delayed another two years. The tunnel was five feet in diameter, and as was true with the spin tunnel, was used primarily for investigation of stability and control.

By tilting the tunnel, its longitudinal axis was set parallel to the path of the model being tested. Controls on the model were remotely operated. A minimum of two men were required to conduct a test: one to adjust the speed of the tunnel to keep the model from moving longitudinally upstream or downstream; the other to operate the remote controls of the model. Changing of the tilt of the tunnel and its airspeed allowed the engineers to test at varying glide paths. Throughout the course of each test, motion picture cameras photographed the movements of the model and its reaction to controls.95


95. Fortune, 23 (March, 1941), 144; "Wind Tunnels at LMAL," November 15, 1943, 4; Pope, Wind-Tunnel Testing, 14; NACA 23rd Annual Report, 1937, 2.
Through the use of this wind tunnel, Langley engineers could experiment with many different ideas to improve stability of an aircraft without having to ask a test pilot to risk his life in a full-size airplane. Later, when research on stability and control increased, a 12-foot free-flight tunnel was constructed. 96 Both of these tunnels were vital to increasing the safety of airplanes.

In order to make tests on models of the flight test results acquired from use of the VG Recorder, a gust tunnel was built in 1936. It was to "obtain information on the reactions of an airplane to a known gust," and determine maximum loads imposed on the aircraft structure. 97 The tunnel had a blower with a maximum jet velocity of about 10 feet per second. A 35-foot accelerating path and a 12-foot gliding section was available before the model entered the vertical gust. 98 Length and arrangement of the tunnel was bounded by the structure of the full-scale tunnel building, in which the gust tunnel was constructed. Both the motion picture

96. NACA 26th Annual Report, 1940, 5-6.

97. Again, this was desired in order to increase airplane safety. U. S. House, Independent Offices Subcommittee, Hearings, 78th Cong., 1st Sess., 1943, 136.

98. Ibid.
camera and a small recording accelerometer were used to gather data on the model's reaction to the gust. As was many times the case at Langley, the success of this tunnel led to larger tunnels of a similar nature.

In general, all technical developments in aeronautics which originated at the Langley Memorial Aeronautical Laboratory represent basically an advancement in the art of wind tunnel research. The innovations for which the NACA is most famous—the cowling, airfoils, low drag wing, and others—all can be traced to the ideas of Langley personnel for increased sophistication in tunnel construction. Certainly without this technological progress, scientific investigation into the phenomena of flight would have been greatly retarded.

Fundamental research in aerodynamics must begin with the accurate measurement of the action of the air on an aircraft and its various parts. The wind tunnel, by reproducing aerial conditions on the ground, made research less dangerous and less expensive. Experimentation by use of the wind tunnel also allowed a much wider range of innovative ideas to be attempted. Much experimentation was carried out by "trial and error"

methods, made possible by the availability of rapid, ground-based wind tunnels. Both military and commercial aviation benefited from investigations in the Langley tunnels. Walter S. Diehl, one of the foremost figures in Naval aeronautical research, for instance, wrote a great number of reports from raw data collected at LMAL. Industry designers also benefited from knowledge acquired from wind tunnel investigations at Langley. There can be little doubt that wind tunnel research at LMAL was one of the most important factors in the advancement of aeronautical science in the United States.

100. Interview with Fred E. Weick.

101. Many of Diehl's writings were published as NACA Technical Reports throughout the years. Interview with Walter S. Diehl.
CHAPTER VI

LANGLEY ENVIRONMENT

An influential factor in the successful operation of the Langley Laboratory was the environment in which the staff conducted research. The laboratory's amiable relations, both internally and externally, proved important in maintaining a genial atmosphere. The organization of the laboratory and the cohesion produced aided in stimulating a beneficial environment for the Langley staff.

During all periods of its history, the leadership of the Langley Laboratory was diversified below the level of the Engineer-in-Charge--Henry J. E. Reid. Activities were divided into relatively autonomous divisions generally designated: (1) Aerodynamics; (2) Power Plants; (3) Technical Services; and (4) Property and Clerical Division. 

Throughout the years other phases of the research work became extensive enough to require the creation of additional divisions, such as the Structures, Physical Research, and Instrumentation Divisions. Each of these was under the general direction of Reid. In a formal sense, the entire laboratory was

under the direction of the Washington officials acting within policies established by the main body of the NACA.

This was the formal structure of the NACA but, in practice, this chain of command was not adhered to in a rigid military sense. To all intents and purposes, the Washington office of the NACA was run by two men: George W. Lewis guiding technical affairs and John F. Victory controlling administrative matters. Since the entire National Advisory Committee met only twice a year and the NACA Executive Committee monthly, Lewis and Victory directed the day-to-day operation of the agency.  

At the laboratory level, each of the various divisions had a single chief who directed its work. H. J. E. Reid, Engineer-in-Charge after 1926, was responsible for the entire operation at Langley. The selection of Reid in late 1925 to head the Langley staff was unquestionably a wise choice. A commanding figure in both appearance and personality, Reid directed activities at LMAL from 1926 until his retirement in 1960.  

2. This conclusion is based on over forty interviews conducted by the author.

well as in name." 4 His earlier experience as chief of instrumentation research had given him a wide vision, encompassing all investigations being conducted at LMAL. His leadership has been described as firm but "always fair to the men working under him." 5

Though never circumventing the leadership, the various research divisions always retained a great deal of autonomy. Problems which did not involve a basic policy shift in research could often be solved at the very lowest levels. Furthermore, because Reid was readily available for consultation, decision-making could often be accomplished without formal procedures. An engineer might tell Reid that a project which had been authorized was not succeeding and an immediate termination of the investigation could be effected without any added expenditures in time or money. 6

Employees of the laboratory, because they had worked with and felt close to those in positions of leadership, also believed their suggestions for research


5. Interview with John P. Houston, June 16, 1967.

6. The informality of many procedures lasted until the staff of LMAL became so large that a more rigorous structure was necessary to maintain efficiency. Interviews with Walter S. Diehl, September 12, 1967; Pearl I. Young, January 10, 1967; and H. J. E. Reid.
projects were given considerable weight. Often Langley employees were appointed as members of the various NACA technical subcommittees and they benefited from discussions with people outside the LMAL staff. Research suggestions might be studied differently from the military or industrial point of view, and Langley engineers gained greater insight from this interchange of ideas. This looseness of command should not be confused with laxness; greater achievements were possible than would have resulted had an inflexible organization been imposed on the laboratory.\textsuperscript{7} Research engineers operate best in an atmosphere of relative freedom.

The relatively "free-wheeling" spirit permeated the entire organization. An extremely young\textsuperscript{8} group of engineers, banded together by their common desire to carry out fundamental research, was able to create a body of information almost unparalleled in governmental sponsorship of scientific activity. The engineers at Langley were fully cognizant that their organization was unique in American scientific development. Only at

\begin{itemize}
\item[7.] This concept was repeated by virtually everyone interviewed by the author.
\item[8.] In January, 1926, the engineering staff was said to "average a little less than 30 years of age." Norfolk \textit{Virginian Pilot}, January 1, 1926.
\end{itemize}
the Bureau of Standards\textsuperscript{9} was government-endowed research carried on in a comparable manner. This sense of efficacy on the part of Langley employees was intensified by both the praise and cooperation they received from the military and the aviation industry.\textsuperscript{10}

The Langley staff was a community in itself. Since the total personnel at the laboratory, both professional and non-professional, did not reach 400 until 1937,\textsuperscript{11} most of the employees knew their co-workers and were aware of the other's research activities. This was, of course, due in part to the nature of the task being undertaken. A research project often involved more than one division at the laboratory, necessitating the association of men who analyzed a problem from divergent viewpoints. For instance, this collaboration helped make intelligible to an electrical engineer involved in instrumentation research, the criteria and difficulties


\textsuperscript{10} Praise also came from newspapers, for instance see \textit{New York Times}, June 1, 1932, 22.

\textsuperscript{11} "Growth of Langley's Staff--Professional, Non-Professional, and Total," June 30, 1959, NASA Historical Archives (NHA).
under which perhaps a test pilot operated. Henry Reid personally promoted this kind of cooperation with a view toward gaining a more cohesive staff.

Geographical proximities were such that walking down a hall could bring one into immediate contact with employees of another research division. One engineer, whose office was adjacent to that of the test pilots, recalls often going next door, proposing a test which required free flight examination, and having the pilot come along immediately to make the flight. The professional employees were given many "opportunities to innovate, both in their research projects and the development of new facilities." Naturally many suggestions originated in the committee and subcommittee meetings of the Washington branch of the NACA but, the Langley staff, and their spokesman, George Lewis, had wide latitude in the initiation of research activities.

Very little discontent or internal strife was evident in the working relationships at LMAL. In the early 1920's one of Langley's prime theoreticians resigned

12. Interviews with Robert E. Mixson, January 9, 1967; Fred E. Weick, October 2, 1967; H. J. E. Reid; and P. I. Young. The test pilots themselves were often also engineers.

13. Interview with Fred E. Weick.

to take a university position as the consequence of a personality conflict with another employee of equal status. 15 Aero Digest, during its attacks on the NACA, charged that internal politics forced a number of capable engineers to accept employment offers from industry, but the charge was never substantiated. 16 The only other evidence of employee dissatisfaction was a letter written to a Washington newspaper during 1939 in which an anonymous Langley employee asserted that the laboratory was referred to as "Dr. Lewis' Concentration Camp." 17 Apart from these relatively minor incidents, no further instances of staff disaffection are evident. Also, the number of bright research engineers who remained with LMAL during their entire careers belies any significant dissatisfaction.

The social life of the employees was another facet of the Langley Laboratory. Although admittedly

15. H. J. E. Reid to G. W. Lewis, January 2, 1931, Langley Research Center (LaRC) Files.


of lesser significance than the research accomplished, this aspect of Langley's history is not without importance in the success of the overall operation. Not only did the staff work together daily as an effectively functioning research team, but they also spent a great deal of their leisure time together. Lasting friendships and intense loyalty to each other resulted from these associations.

For many years, social functions for the Langley employees were conducted by an employee-originated and operated organization—The Noble Order of the Green Cow. The Green Cow, as it was popularly called, developed as the result of an attempt to improve the cultural level of the laboratory staff. It was decided about 1923—nobody remembers who made the decision—that the employees should hold a tea party so all the staff could enjoy a social gathering with their co-workers. Following the event, however, some grumbling about the stolidness of the party was noticed. Robert E. Mixson, Carleton Kemper and others determined that actually, what the workers desired was an organization to coordinate "beer parties" in a much more relaxed atmosphere.18

Such an organization was created by the employees and resulted in a great deal of camaraderie among the

18. Interview with Robert E. Mixson.
entire staff. During the period in which the small number of employees permitted, the Green Cow also conducted "initiations" of new Langley personnel. All social functions were held off the laboratory grounds and the Green Cow was never made a formal part of the LMAL organization. In this way, no complaints could be lodged at the door of the laboratory if a participant at one of the parties became high spirited. The construction of a Morale Activities Building on Langley property in 1942 eventually led to the demise of the Green Cow. To use the new building, a formal employee social committee had to be established. With the rise of a laboratory social organization, the Green Cow, having well served its purpose, was phased out of existence.\(^{19}\)

A social organization allowed Langley personnel to work together and to relax together. One engineer has described the atmosphere at the laboratory as "much like a college fraternity" with its attendant frivolity.\(^{20}\) With a number of young, unmarried engineers on the staff, a considerable amount of practical joking occurred.\(^{21}\) Thus the total environment at LMAL served

\(^{19}\) LMAL Bulletin, June 5, 1943.

\(^{20}\) Interview with Peter F. Korycinski.

\(^{21}\) There are a great many stories which one could relate in this context, but two of the best the author has heard follow. One night a group of LMAL engineers living together in a rented house heard a
to keep the employees generally in an enthusiastic state of mind, which naturally aided in the success of the institution.

The unity of purpose was evident in the aftermath of a near-disaster at the laboratory. On August 23, 1933, an extremely severe rainstorm inundated nine of the eleven LMAL buildings with salt water which reached a depth of five feet in some areas. Many of the Langley staff rushed immediately to the laboratory, removed their shoes, rolled up their trousers, and by candlelight began recovering as much equipment as possible.  

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horn blowing on one of the roommate's cars. Another roommate, not bothering to wake the owner, wandered out in the night with a wire cutter, opened the car's hood, and snipped indiscriminately until the correct wire was found—and then went back to sleep. (The names of the participants are excluded, as both are now high officials with the NASA.)

A second story is of the head of one of the wind tunnel groups going golfing (for the first time) with two subordinates. The subordinates acquired for their boss a golf bag with a broken strap, and filled it with extra clubs and an eight-pound piece of lead—and then told their superior that it was unsportsmanlike to hire a caddy! The tunnel chief carried the extra-heavy bag for an entire round of golf.

Both stories told to author in confidence.

22. U. S. House, Committee on Appropriations, Subcommittee on Independent Offices, Hearings, 73d Cong., 2d Sess., 1934, 182. (Hereafter cited as Independent Offices Subcommittee.) One engineer, now Director of one of the NASA research centers, recovered all his materials because, although the water reached desk-top height, all his materials were on top of his desk. Interview with John F. Parsons, June 16, 1967.

23. Interviews with Elton W. Miller, February 8, 1967; and H. J. E. Reid.
After electric current was re-established, six days later, an investigation was carried on to determine the extent of the damage. Although Henry Reid originally estimated the damage at $160,459, prompt repairs authorized with PWA funds "to restore the laboratory to an operating condition," held the cost to $47,944. In repairing the equipment, safeguards were established against a recurrence and, when a similar storm occurred in 1936, replacement costs amounted to only $2,111.

Another aspect of the unity among the employees resulted from the general hostility of the residents of Hampton toward the laboratory staff. This animosity was not surprising for a couple of reasons. In the first place, most of the professional employees had grown up and been trained in the North. Hampton, a relatively small southern community in the 1920's and 30's, viewed the staff as "outsiders" with ideas and attitudes quite

24. E. R. Sharp, Memo for Files, August 29, 1933, LaRC Files.


27. H. J. E. Reid to NACA, September 28, 1936, LaRC Files.
different from their own.\textsuperscript{28} This attitude was not necessarily incorrect. In 1923, Leigh M. Griffith, LMAL Engineer-in-Charge, was invited to a luncheon of the local Rotary Club and, when asked to make a few appropriate remarks, told the assembled Rotarians exactly what he felt was wrong with the city of Hampton.\textsuperscript{29} Actions such as this were not designed to promote harmonious relations between the community and Langley Laboratory employees.

Problems with several Hampton merchants arose in two respects. For many years Langley employees were given the privilege of purchasing goods from the Post Exchange on the Army Air Service portion of Langley Field. As prices in the PX were lower than those in the Hampton stores, the local businessmen, correctly, felt this was unfair competition with respect to civilians. To avoid criticism, the Army ruled that LMAL employees were no longer to have purchasing privileges on the post. Thus the problem was settled. Another complication with the local businessmen was the desire of LMAL engineers—because of their training—to ask for a complete technical explanation of any appliance they

\textsuperscript{28} Interview with P. I. Young; Richard V. Rhode to author, January 23, 1967.

\textsuperscript{29} Interview with H. J. E. Reid.
wished to purchase—often criticizing the entrepreneur for his lack of knowledge. 30

With the passage of time, many of the strains in the relationship with the community were overcome. H. J. E. Reid, after assuming leadership of the laboratory, was a key figure in smoothing out differences. He belonged to many local service organizations and was quite active in community affairs. 31 Other Langley employees followed the example of Reid and became involved in community activities. Since many of the non-professionals on the staff were natives of the area, they further helped in assimilating NACA personnel in the community. Naturally rapport improved with the "increasing economic importance of the laboratory to the area as the laboratory grew in size." 32 Social interaction between Hampton's young ladies and the unmarried engineers at Langley further eliminated friction. Often men who had been referred to as "NACA Nuts," became instead sons-in-law, and were fully accepted in the

30. Both stories told to the author by Pearl I. Young.

31. NACA Executive Committee Minutes, February 5, 1926, say "relations with the community were improved after Reid [took] over direction of the laboratory."

community. After the initial period of strain, relations between Langley personnel and residents of Hampton steadily improved and became harmonious.

Working conditions between Langley and NACA Headquarters were, for the most part, extremely cordial. Director of Aeronautical Research George W. Lewis was of primary importance in this regard. His frequent trips to the laboratory and very real interest in the welfare


34. Disregarding the "natural animosity" between researchers and administrators, pointed out by the following verse, entitled "Ballad of Charlie McCoffus":

A young Field engineer named Charlie McCoffus
Worked all day in the field and at night in
the office,
Preparing reports and estimates too
To be picked all to bits by the Washington crew.

For the boys in D.C. and their double lensed
specs,
Their sallow complexions and fried collar necks,
Care not for the time or trouble they make
If a comma is missing, or a carbon misplaced,

They fire it back with ill conceived jeers
To harrass the poor hard working field engineers.

To get back to Charlie, he struggled along
Till an ache in his head told him something
was wrong.
Then went to the doctor and "Doctor" says he,
"There's a buzz in my brain. What's the matter
with me?"
of the personnel won him the respect of all employees. In addition he insured the concept of "promotions from within." Supervisory personnel within the agency were always (with a single exception) recruited from the ranks of engineers who had worked at LMAL. Lewis attempted, and was quite successful, in providing equal opportunities for all laboratory employees.  

Well the medico thumped as the medicos do
And tested his pulse and reflexes too,
And his head and his heart and his eyes and each lung
And Charlie said "Ah" and stuck out his tongue.

Then the doctor said "Well what a narrow escape!
But a brief operation will put you in shape.
I must take out your brain for complete overhauling,
In the interim take a respite from your calling."

The weeks passed by and Charlie McCoffus
Never called for his brain at the medico's office.
The doctor got worried and gave Charlie a ring.
"You'd better come over and get the damn thing."

"Thanks Doc, I don't need it" said Charlie McCoffus,
"I've just been transferred to the Washington Office."

So Charlie now wears a fried collar to work,
And hides in the lairs where the auditors lurk,
And his letters bring tremors of anger and fear
To the heart of each hardworking field engineer.

And the pride and joy of the Washington Office
Is brainless predacious young Charlie McCoffus.

Copy given the author by Robert E. Littell.

35. Walter S. Diehl, long-time observer of LMAL activities, says that he usually agreed with the quality of the choices made when one was selected for a position of leadership. Interviews with W. S. Diehl and H. J. E. Reid.
NACA Headquarters' actions in acquiring funds were also of great importance for continuance of LMAL activities. Each year, the bulk of testimony before the House Independent Offices Subcommittee, during budget hearings, was given by NACA Executive Committee Chairman Joseph S. Ames, and George W. Lewis. Dr. Ames, especially in the early 1920's, was hesitant about the value of his testimony. He felt that questions the committee would ask would tend to be more political than technical in nature. He was pleasantly surprised by the intelligence, if not deep technical knowledge, shown by the members of Congress who had control of the NACA budget. As a result of his straightforward testimony, Ames won the confidence of the members of the appropriations subcommittee and his pronouncements were generally accepted at face value. Indeed Dr. Ames was held in such high regard that when Director of the Budget, Herbert M. Lord asked, during the Coolidge Administration, for "contributions" from expenditures to reduce the federal debt the NACA was the only government agency which did not lose money. 36

Not until the depression years of 1932 and 1933, in fact, did the NACA receive a smaller budget

appropriation than had been requested. Through the depression years, however, the agency received many reminders from the administration of the need for economy in expenditures due to the precarious state of the national economy. The need for economy forced the agency to adopt a policy of not allowing pay increases for Langley employees. In general, however, LMAL employees were satisfied in having a steady job while so many others were unemployed. The laboratory hired as many unemployed Hampton residents as possible—often for menial tasks—to help reduce difficulties in the area.

The NACA was careful, even in the depression years, always to praise Congress for supporting the research efforts of the Langley Laboratory. This praise was often coupled with a description of the economic value of research conducted at Langley, thereby


38. See NACA Minutes, 1930-1939, passim.

39. Interview with John B. Parkinson.

40. Interview with W. Kemble Johnson, June 27, 1967.

41. For example, see NACA 15th Annual Report, 1929, 2; and NACA 18th Annual Report, 1932, 1.
justifying increased budget requests.\textsuperscript{42} International competition in aeronautical developments was also pointed to in appropriation testimony: "The nations of the world," John F. Victory asserted, "...are building newer and more modern equipment than we have at Langley Field." Although he contended LMAL was, in 1936, still the finest aeronautical research laboratory in the world, Victory said new equipment was necessary "in order to keep our present advantage."\textsuperscript{43}

NACA budget requests did not altogether escape criticism. \textit{Aero Digest}, of course, felt that most of the funds NACA requested for research at Langley was wasted. George Lewis and John Victory were charged with running primarily a political rather than a research-oriented agency. Friends of the agency on the staff of \textit{Aviation} provided a defense, saying that the NACA had upheld its function of research and had not pre-empted industry's activity by building complete airplanes. "If the industry is to get the benefit of the studies made

\textsuperscript{42} A 1933 document contended that annual savings resulting from LMAL investigations totaled $10,507,904, far in excess of its total expenditures. "Economic Value of the National Advisory Committee for Aeronautics," January, 1933, LaRC Files.

by it [LMAL], the industry will have to take the results and apply them in service equipment." Later, a Senate committee investigating the national defense program charged that the NACA, prior to World War II, had shown "timidity in requesting adequate Congressional appropriations." NACA leaders had, they felt, requested enough funds to carry out their primary function of supervising and directing "the scientific study of the problems of flight." Budget requests were also based on what Ames, Lewis, Victory, and the Langley administrators could reasonably expect Congress to appropriate. During the depression, and immediately following World War II, NACA's appropriations dropped. In general, however,

44. "Perhaps Farewell, Lewis and Victory," Aero Digest, 22 (January, 1933), 18; "Competition For Carburetors," Aviation, 32 (October, 1933), 325. By 1935, Aero Digest had overcome its worry, saying "The N.A.C.A. is a non-political organization of aeronautical experts, engaged in research. Its findings are based, not upon guesses or political expediency, but upon fact." Cy Caldwell, "The Man on the Flying Trapeze," Aero Digest, 27 (October, 1935), 20.


the amount of funds and the subsequent amount of research conducted, steadily increased. 47

Vital propaganda was carried out by the NACA Washington office at times when threats arose to its continued existence as an independent agency. Senator William E. Borah, Republican of Idaho, introduced a resolution in 1921 to abolish the NACA and transfer its duties to the Bureau of Standards, and its land to the War Department. Lack of support caused the resolution to be dropped. 48 In the same year a question was raised by the House Independent Offices Subcommittee as to whether the original NACA bill, allotting an annual appropriation of $5,000, pre-empted the right of the House to grant the NACA any additional money. Dr. C. D. Walcott, NACA Chairman, answered that the original bill intended that there be additional appropriations, an argument which the committee accepted. 49 John F. Victory visited Congressional friends of the agency whenever a threat arose.

47. The appropriation grew from $200,000 in 1921, to over $30,000,000 in 1947. See "NACA Budget Requests, and Appropriations," NASA Budget Office.


The most serious threat to NACA's (and therefore Langley's) independence came during the administration of President Herbert Hoover. During his tenure as Secretary of Commerce, Hoover had made overtures, to no avail, toward bringing the NACA into the Commerce Department's Bureau of Standards. As President, Hoover, on December 9, 1932, signed an Executive Order transferring the NACA to the office of the Secretary of Commerce and the Langley Laboratory to the Bureau of Standards.\(^{50}\)

Immediately following the issuance of the Executive Order, the NACA began marshalling its friends in opposition to the plan. Reginald M. Cleveland editorialized in the *New York Times* that the NACA's work at Langley Field had "been of basic importance in leading to improvements in the safety, efficiency and performance of both military and commercial aircraft," and criticized Hoover's plan to remove the autonomy of the Advisory Committee.\(^{51}\) Charles A. Lindbergh stated his opposition

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50. U. S. President, Executive Order No. 5960, *Consolidation and Coordination of Governmental Activities Affecting United States Commerce*, December 9, 1932. J. F. Victory to J. S. Ames, December 10, 1932, NHA. Hoover was supported by Republican Senator James Couzens of Michigan, who felt that NACA research was "conducted chiefly for large aviation companies." "Aviation Research," *Science*, 76 (July 8, 1932), Supplement, 8.

to the transfer both in a letter to Dr. Ames and in a public statement declaring; "It appears to me that the present period of rapid advance in technical improvements and application of aircraft to American commerce is not an opportune time to make any move which would impair the efficiency of the National Advisory Committee." Undoubtedly Lindbergh's popularity made him extremely influential in opposition to the Hoover proposal.

Connecticut Republican Senator Hiram Bingham, although a lame duck, added his voice to the opponents of reorganization, agreeing that any change in the status of the NACA would be unwise. In January, 1933, the NACA issued a report which strongly opposed placing the NACA under the Secretary of Commerce. This statement was signed by thirteen major leaders in American aviation. With this opposition from respected figures,


53. Hiram Bingham to J. S. Ames, January 6, 1933, NHA.

54. Signing the report were: J. S. Ames, President of Johns Hopkins University; Charles G. Abbot, Secretary, Smithsonian Institution; Captain Arthur B. Cook, U. S. N.; Professor William F. Durand, Stanford University; Major General Benjamin D. Foulois, U.S.A.; Harry F. Guggenheim, U. S. Ambassador to Cuba; William P. MacCracken, Jr.; Charles F. Marvin, Chief, U. S. Weather Bureau; Rear Admiral William A. Moffett, Chief, Bureau of Aeronautics, U.S.N.; Brigadier General Henry C. Pratt, U.S.A.; Dr. D. W. Taylor; Edward P. Warner, editor
the House of Representatives voted down (203 to 176) the Hoover plan for government reorganization. This kept the NACA from abolition and LMAL from becoming a part of the Commerce Department. With one exception, a half-hearted attempt in 1937, the NACA suffered no other significant threats to its existence until its eventual consolidation into the National Aeronautics and Space Administration in 1958.

More directly important to research conducted at LMAL were the cordial relations with both the military and the aviation industry. Following the early disputes with the Air Service over living quarters for the NACA personnel at the laboratory, cordial associations were established. A change in leadership of the NACA and Air Service contingents at Langley Field was important in reducing the earlier animosities. Colonel Charles H. Danforth, who replaced Major William Hensley, and Henry J. E. Reid of LMAL formed an excellent working alliance,

55. New York Times, January 20, 1933, I. The vote, of course, was on the entire Hoover reorganization plan.


57. See Chapter III.
without interfering in each other's assigned duties.\textsuperscript{58} The only difficulty at Langley Field between LMAL and the military was an annual message from the base commander asking that LMAL employees please try to observe the speed limits on the post. Reid in each instance issued a memorandum to the staff forwarding this request.\textsuperscript{59}

Further, close contact with both the Army and the Navy was maintained by the continuing presence of officers of each service on the National Advisory Committee. Even before the Laboratory was completed, the NACA sent one of its engineers to assist the Aircraft Production Board in the development of the Liberty engine for possible deployment in World War I.\textsuperscript{60} To further coordinate the work being conducted by LMAL with that of the Air Service, J. S. Ames visited Thurman H. Bane, director of aeronautical investigation for the Air Service at McCook Field. This visit helped to avoid any duplication of effort by the NACA and Army research

\textsuperscript{58} J. F. Victory to C. D. Walcott, August 1, 1922, NHA.

\textsuperscript{59} Memos and base commander's requests are in File E27-7, LaRC Files.

\textsuperscript{60} "Men and Machines," Unpublished manuscript, NHA, 124.
teams. Ames also sought to insure that not all of the NACA research effort was directed toward military problems, but that it serve commercial interests as well. The charge of duplication of efforts haunted LMAL throughout its history. This assertion was answered consistently in the same manner: (1) the research at LMAL was fundamental whereas the Army investigations were in the area of applications of these research findings; and (2) discussions in meetings of the NACA and its technical subcommittees served to prevent any duplication.

Generally the NACA received important assistance in its work from the military. Most of the airplanes used in free flight testing were borrowed from one of the services, and LMAL had virtually a free hand in doing what it wished with these aircraft. Many of the planes were sent to Langley at the behest of Commander Walter S.

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61. J. S. Ames to Charles T. Menoher, January 5, 1920, "Biography File," (Bane Folder), Box 3, Record Group 255, National Archives.


63. See, for example, U. S. Senate, Committee on Appropriations, Hearings on Sundry Civil Appropriations Bill, 66th Cong., 3d Sess., 1920, 60; and U. S. House, Select Committee of Inquiry into Operations of the United States Air Services, Hearings, 68th Cong., 1925, II, 736. Yet another repetition of the same argument is in U. S. House, Committee on Interstate and Foreign Commerce, Hearings Before the President's Aircraft Board, 69th Cong., 1st Sess., 1925, 348.
Diehl of the Navy. Diehl would convince the Chief of the Naval Bureau of Aeronautics that LMAL needed a particular airplane to run a test for the Navy and that the Navy should lend them the airplane. There were instances, in fact, in which the Navy itself would make a payment directly to the Committee to finance an investigation. Both the Navy and Army Air Service provided funds when they desired a specific investigation to be performed "for which the committee [had] not the necessary funds."

Billy Mitchell, still an important figure in military aviation, continued his antagonism toward the laboratory. He said that LMAL used "large appropriations of money for matters that could be handled far better in a central engineering aeronautical department." This dislike was mutual; John F. Victory, who worked for

64. Later the Navy purchased airplanes which were tested at LMAL, and often even financed the cost of extra wings undergoing examination. Interview with Walter S. Diehl.

65. For example, in 1923 the Navy desired to have LMAL investigate a TS airplane to determine low flying speed, landing speed, stalling speed, and take-off speed of the aircraft. For this, the Navy transferred $24,000 to the Committee. Research Authorization No. 97, October 18, 1923, LaRC Files.


the NACA throughout its entire life, has said that Mitchell "made more enemies for aviation than any other man, in or out of aviation. All the constructive forces of aviation," Victory contends, "had a harder uphill fight to overcome the ill-will engendered by Billy Mitchell's loose talk and wild claims." Victory also asserted that Mitchell desired to abolish the Navy's aviation program. In testimony before the Florin Lampert Committee investigating the air services in 1925, Mitchell accused the NACA of taking political sides on the question of military aviation because "its [NACA] offices are in the Navy Building."69

Despite the difficulties with Mitchell, relations between the NACA and the air service branch of the Army were generally quite amiable. A survey of research authorizations reveals many investigations made at the direct request of the Army Air Service.70 In addition to the investigations conducted by the Laboratory, non-research favors were granted by LMAL to Air Service personnel. In 1928, for example, Edward R. Sharp, LMAL


70. All Research Authorizations are in the files of the Langley Research Center.
Administrative Officer, allowed the Army to use the NACA boat "Retriever" to provide pleasure rides for visiting West Point Cadets, and officers and ladies of the post. In addition, Colonel Danforth was allowed to fly NACA aircraft whenever he desired, and often the Air Service engineering officer at Langley Field was granted the same privilege.

The military realized the value of LMAL research and acknowledged its dependence on the investigations performed there. General Mason M. Patrick, Chief of the Air Service, in a letter written to the Bureau of the Budget in 1922 agreed that the "Army Air Service depends upon the National Advisory Committee for the study and solution of the more difficult [aeronautical] problems." A representative example of praise by the Navy is in a 1935 statement of Rear Admiral Ernest J. King. "The most fundamental factor underlying the rapid progress in American aeronautics is the scientific

71. See W. V. Andrews to E. R. Sharp, June 12, 1928; and E. R. Sharp to Colonel Culver, June 13, 1928, LaRC Files. The Army officers also used the LMAL recreation camp for picnics. E. R. Sharp to W. J. Davies, June 11, 1928, LaRC Files.


73. Quoted in NACA 8th Annual Report, 1922, 49.
research conducted by the National Advisory Committee for Aeronautics." 74

In many instances, the military cooperated with the laboratory by formally requesting a research project which it had not originated. Both the aviation industry and LMAL would encourage the military to address a letter to NACA Headquarters proposing a particular investigation. This provided the NACA with more substantial justification for carrying out the study, than would have been possible with an internal proposal. 75 Although Dr. Ames claimed that research at LMAL was concerned "only incidentally in working out military aircraft problems," the aviation services gained tremendously from the work accomplished by the laboratory engineers. 76

During the 1930's some feeling of competition existed between engineers at LMAL and those employed by the Army at Wright Field (formerly McCook Field), Ohio. Some LMAL personnel were reluctant to discuss research ideas with their Wright Field counterparts,

74. New York Times, April 7, 1935, IX, 17. One could go on endlessly with quotations from the military praising the NACA, but these two are representative of the period preceding World War II.


fearing the military would use the concepts "as a basis for contract research projects...sponsored by the military." Langley personnel desired to implement their own research ideas rather than allow another organization to "have all the fun and get all the credit." Other than minor strains, however, the bond between the Langley Laboratory and the military proved quite beneficial to both parties. Cooperation was expanded and indeed, proved to be of priceless value with the approach of World War II.

Equally important to LMAL success were cordial relations with the American aviation industry. Little competition evolved between the industry and LMAL. While the industry was designing and building aircraft for sale, the laboratory conducted fundamental investigations, the results of which aided the designer. In non-research areas also, the NACA assisted the manufacturers. The cross-license agreement between airplane manufacturers and the development of legislation to benefit the industry were two areas in which the NACA exerted its influence.


78. See Chapter VIII.
In return, the NACA was generally supported by industrial executives in the Advisory Committee's budget requests. 79

Other methods were employed by the NACA to maintain a beneficial working relationship with the industry. At times when research was being conducted which was of interest to a particular company, that firm's engineers would be invited to confer with their counterparts at LMAL. 80 On the headquarters level, industrial critics of NACA research policy were placed on the technical subcommittee dealing with their area of interest. Then these critics could see first hand, "that constructive criticism was not easy." 81

Frank H. Russell, Vice-President of the Curtiss Aeroplane and Motor Corporation, spoke in 1921 of the assistance LMAL had been to his company. Langley

79. The cross-license agreement, reached in 1917, prevented the prospect of an involved patent suit which might have greatly retarded the growth of the American aviation industry. Legislation which the NACA supported included the 1925 Kelly Act, the Airmail Act of 1934, and the 1938 Civil Aeronautics Act. Interviews with John F. Victory, June 21, 1967; and William L. Littlewood, October 4, 1967. In 1917, the NACA and the manufacturers established a special committee to "arrange details for speeding up production of aircraft." New York Times, March 23, 1917, 8.

80. Interview with Joseph N. Kotanchik, June 27, 1967. These visits were separate from the annual inspections.

investigations on pressure distribution had shown the Curtiss Company why its aircraft had been having trouble with ailerons. "Immediately we changed our formula," Russell said, "for the strength required in the construction of the aileron."82 In subsequent years the Douglas DC-3 and Boeing B-17, among others, also benefitted greatly from LMAL research.83

Most of the basic research which later became the basis for the B-17 "Flying Fortress" was completed at Langley. Boeing's debt to the NACA was acknowledged widely when the B-17 was unveiled. C. N. Montieth, Vice-President and Chief Engineer of Boeing Aircraft, told John F. Victory that the airplane was "NACA from start to finish."84 In a letter to the NACA, Montieth gave credit to the agency for the "balanced flap," and cowling, both of which were part of the B-17 design. He further admitted that the Boeing Company leaned "rather heavily on the committee for help in improving our

82. U. S. House, Independent Offices Subcommittee, Hearings, 67th Cong., 2d Sess., 1921, 386. An aileron is a section on the corner of a wing which balances the airplane laterally.


84. Interview with John F. Victory, June 21, 1967.
work.\(^8^5\) The 1938 *Aircraft Yearbook*, an industry publication, agreed that the B-17 was a "symbol of the NACA's practical research through the years." Inspection of the airplane revealed the results of LMAL studies, "represented by such features as cowling, engine housing, engine position, wing section design, VG Recorder, data on pressure distribution upon wings and tail surfaces made use of in the construction, and data on flaps."\(^8^6\) Further investigation was made at LMAL on the flying qualities of the B-17 at the request of the Army.\(^8^7\)

Investigations undertaken at direct request caused the only minor strain in the otherwise friendly relations between the NACA and the industry.\(^8^8\) Although in most instances LMAL did not receive payment for the research,\(^8^9\) the requesting company desired the information gathered rapidly. Often completion of the research took


\(^8^7\) Research Authorization No. 630, August 19, 1938, LaRC Files.

\(^8^8\) Although, occasionally LMAL would deny a request because of budget or time limitations. For instance, see A. Kartveli to G. W. Lewis, May 20, 1938, and Lewis to LMAL, May 23, 1938, LaRC Files. Interview with Grover C. Loening, October 4, 1967.

\(^8^9\) Interviews with Ralph E. Ulmer, December 20, 1966; and William L. Littlewood.
many months. Langley policy was to withhold the test results until they were complete and accuracy of the data was guaranteed. This was necessary to retain the high status of laboratory investigations. Other considerations granted to the industry tended to outweigh these slight problems.

In 1926 an event occurred which proved very beneficial to LMAL-industry relations. This was the institution of a so-called "annual inspection" of the laboratory by industrial representatives. One former laboratory employee has likened the inspections to "putting on a parade for parents on the last day of school." And, as parents are usually impressed by what their children have done, the industry gained a vicarious feeling of pride in what the NACA had accomplished.

An enormous amount of planning and preparation was undertaken to make these annual affairs a success.

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90. Interview with Howard W. Kirschbaum.

91. For instance, when circumstances forced cancellation of the annual conference at LMAL, arrangements were made to allow individual staff conferences for manufacturers' representatives. NACA 26th Annual Report, 1940, 21.

92. Interview with Pearl I. Young, January 10, 1967.

John F. Victory generally took upon himself the responsibility for the direction and coordination of the yearly occurrence. He arranged for all the "important people" to be invited, and correlated the activities planned for the event. Committees were established at the laboratory for transportation of the visitors and the programs to be presented. The period of planning ranged from three to six months prior to the event, usually held each May.

Once laboratory committees had prepared their demonstrations, Victory conducted a rehearsal and offered suggestions for improvement. He eliminated material which would be, in his opinion, too technical for the audience. As a non-technician himself, Victory realized that the Langley engineers might, by using a vocabulary which the guests could not understand, waste their preparations. Following this, participants rehearsed their roles until a state of "near-perfection" was

94. Military personnel, academicians involved in aeronautics, writers from the aeronautical journals, and Congressional leaders were also invited. In later years, attendance grew to such an extent that the inspection was held over a two-day period, with different groups attending the same program on separate days. Interview with John F. Victory, June 22, 1967.

reached. By the time the inspection was held, each demonstration was given in a most professional manner. 96

As originally conceived, the annual affair was to be a conference of all those interested in the advancement of aeronautical research. Guests were brought to the laboratory in one group, traveling from Washington on an overnight boat ride--during which considerable frivolity occurred. Arriving at the laboratory following a NACA-sponsored breakfast at the Chamberlain Hotel in Hampton, the visitors listened to discussions of equipment and research accomplished during the previous year. 97 After completion of the oral presentations, guests were taken on a tour, during which new laboratory equipment was operated and explained. If feasible, a demonstration would be conducted to give the

96. Interview with J. F. Victory, June 22, 1967. Grover C. Loening and William L. Littlewood, both guests at many inspections as representatives of the aviation industry, agree that the programs were always presented with a great deal of finesse. Interviews with Loening and Littlewood.

visitors an understanding of some problems the research engineer encountered. 98

In the afternoon, the assemblage was divided for special technical conferences 99 at which various research problems and proposals were discussed. The conferees tendered many suggestions for LMAL research projects. The first suggestion that LMAL conduct investigations in cowling and cooling of engines, for instance, was offered at one of these annual conferences. 100

The gathering together of the representatives of industry, along with military and academic figures interested in aviation, was a very beneficial by-product of the occasion. In the festive atmosphere which enveloped the inspection, all participants freely discussed their common aeronautical problems.

98. For example, see "Research on Parade," Aviation, 33 (July, 1934), 201-04; and Alexander Klemin, "Langley Field Engineering Conference," Aero Digest, 26 (June, 1935), 20-22, 36.

99. For instance, at the Twelfth Annual Inspection, six separate afternoon conferences were held. Topics discussed were: (1) airplane performance and design characteristics; (2) aerodynamic efficiency and interference; (3) cowling and cooling research; (4) aircraft engine research; (5) seaplanes; and (6) rotorplanes. Michael Watter, "Aircraft Engineering Research Conference," Aero Digest, 30 (June, 1937), 22-23, 90-91.

100. Interview with Fred E. Weick.
The public relations benefits to the Langley Laboratory as a result of the annual inspections are incalculable. Much good will for the NACA and its laboratory was created by the event. Also, following the meeting, aviation journals and newspapers generally praised the laboratory for the investigations conducted and results achieved: the free publicity was a great value when the NACA appeared before the Congressional appropriations committee.

All facets of life at LMAL, including its relationships with outside influences, combined in the success of laboratory activities. The laboratory did not conduct its work in a vacuum. As the state of the aeronautic arts evolved, the Langley Laboratory joined and often led this growth. Cooperation in all respects was necessary for the advancement of aviation in the United States.

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CHAPTER VII

MAJOR INVESTIGATIONS, 1927-1939

The most productive period in Langley's history, in terms of important research accomplished, was between the Lindbergh flight in 1927, and the beginning of the Second World War in Europe in 1939. During these years, Langley personnel carried out investigations which had a lasting effect on American aeronautical development. Langley engineers conducted research into virtually every area of the phenomena of flight.

Among the most important studies concerned the reduction of drag which is of great importance in increasing the efficiency of an airplane. Drag, that is, air resistance, has two separate aspects: induced drag, associated with the production of lift; and that produced by those parts of an aircraft which provide no lift. The latter form, called parasite drag (also skin friction or profile drag), can be caused by such parts of an aircraft as wheels, landing gear, rivet heads, or engines—anything which interrupts the smooth flow of air over an aircraft. Any reduction in amount of drag will result in the saving of engine power and a commensurate rise in the total
efficiency of an aircraft.\(^1\) LMAL engineers expended lavishly of research time and funds in various attempts to reduce aircraft drag.

In the middle of the 1920's both the Navy and the aviation industry had become very interested in the development and use of a radial air-cooled engine on aircraft. The Navy felt the water-cooled engine impractical for use in flying off a carrier.\(^2\) On the other hand, the air-cooled engine faced a problem of excessive drag because its cylinders projected unevenly from the engine. Although the engine was effectively cooled in this manner, jaggedness of the flow surfaces over which the cooling air moved caused an increase in cowl drag.\(^3\) To overcome the drag problem of an air-cooled

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engine, Langley undertook a project which reaped the laboratory a tremendous amount of favorable publicity.

Until construction of the twenty-foot propeller research tunnel neared completion in 1927, no facility existed to conduct a systematic series of tests on various engine cowling designs. At the first annual conference in 1926, military and industrial representatives suggested that cowling research be one of the first investigations in the new tunnel. The Naval Bureau of Aeronautics, in June, 1926, formally requested an investigation "to determine the effect of various forms of cowling on the drag characteristics of a pursuit airplane and on the cooling characteristics of an air-cooled engine." Langley engineers used a Wright Apache airplane with a "Whirlwind" engine for these tests.

By the time the PRT was completed, on November 30, 1927, Fred E. Weick, who was employed to supervise research therein, had devised a logical series of tests

4. See Chapter V.

5. Interview with Fred E. Weick, October 2, 1967.

to determine the most effective engine cowl. He determined that a systematic series of tests should be conducted at steps ranging from a completely enclosed engine to one with no cowling at all. Weick outlined a program for tests along this line and then "submitted [it] to the manufacturers for criticisms and suggestions, several of which were adopted." The investigation procedures carried out in the propeller research tunnel called for a complete encasement as aerodynamically smooth as possible. Wind tunnel examination pointed out that the "drag of the cabin fuselage with an uncowled engine was...more than three times as great as the drag of the fuselage with the engine removed and the nose rounded." This gave the engineers a standard to proceed from in the subsequent cowl tests. Obviously the entire engine could not be encased as no air cooling would then be possible.

7. At the same time, H. C. H. Townend in England was developing the so-called Townend Ring to attack the drag problem with the air-cooled engine. There is no evidence that Townend or Weick was aware of the other's investigations. Interview with F. E. Weick; Naylqr and Ower, Aviation: Its Technical Development, 146-47.

8. Interview with Fred E. Weick.


10. Ibid., 165.
Problems of cowling were therefore twofold: the cowl had to reduce the overall drag of the aircraft; and the air had to be led in, directed around the engine parts which required cooling, and led out again in a relatively smooth manner. Plans called for testing various cowlings of the Wright "Whirlwind" J-5 engine on fuselages of both a cabin monoplane and an open-cockpit biplane. Smaller cowl designs were tested on the open-cockpit fuselage.

The researchers designed and constructed ten separate cowlings, each with a different amount of covering. Weick determined that air could be brought in most efficiently through the center of the body of the cowl. This would create the least internal disturbance. The top portion of the cowl could be designed for smoother flow around the exterior of the cowl. First, the engineers examined the cooling effectiveness of each design by attaching thermocouples to the engine in order to measure the temperature of each cylinder. If necessary, each cowl was then modified to ensure adequate cooling.

11. Interview with Fred E. Weick.
14. F. E. Weick, Aviation, XXV (November 17, 1928), 1556-57, 1586-90.
Besides permitting cooling of the engine, the cowl could reduce the drag, and thereby increase the efficiency of the aircraft. Next therefore, cowls which sufficiently cooled the engine were tested for drag and effect on propulsive efficiency. Results of the drag tests showed that the so-called "No. 10" cowling, a single unit covering the entire engine with air directed at the hottest portions of the cylinders and crank case, was best. LMAL engineer Elliott G. Reid, who had been conducting wind tunnel research on wing slots, designed the exit slot of the cowl. This led the air out smoothly along the surface of the airplane.\textsuperscript{15} Weick warned, however, that adaptations of this cowl "must be carefully designed to cool properly."\textsuperscript{16}

Once wind tunnel investigations had been completed, the LMAL Flight Operations Section arranged flight tests on a full-size airplane, equipped with the cowl. The laboratory test pilots, under the direction of Tom Carroll, borrowed a Curtiss AT-5A airplane from the Army

\textsuperscript{15} Spinners were also tested in an attempt to improve flow but resulted in too little gain for the physical problems involved in their adaptation to the aircraft. Interview with Fred E. Weick.

Air Service at Langley Field. Following the adaptation of a No. 10 cowling to fit the AT-5A, Carroll and his associate William H. McAvoy conducted a series of instrumented flight tests. In flights prior to the cowling addition, maximum speed of the aircraft was 118 miles per hour at 1,900 rpm. With the cowling, at the same rpm, the plane reached a speed of 137 miles per hour. The test pilots further attested that with the cowling additional smoothness of operation and flying qualities resulted. 17

In effect, this work ended the intensive research conducted by the Langley Laboratory on cowlings. Joseph S. Ames, Chairman of the NACA, publically announced the results of the cowling research on November 9, 1928. He contended that the cowling could be installed on an airplane as standard equipment at a cost of about $25,00. 18 As was true with all Langley discoveries, the NACA exerted little pressure for the adoption of the cowl on military or commercial aircraft. It was the policy of the agency to disseminate the results of its


investigations to a wide audience and to let the manufacturers employ the data at their own discretion. 19 Industrial design engineers did, however, generally agree to the merit of the cowl and often sent their proposed designs to Weick and his associates for comment and criticism. 20 LMAL staff engineers aided the industry in this manner in order to promote good will for the agency.

Widespread acceptance of the value of the NACA cowling resulted from the record-breaking flight, and attendant publicity, of Frank M. Hawks on February 4-5, 1929. Flying in a Lockheed Aircraft "Air Express" equipped with a NACA cowling, Hawks and Oscar E. Grubbs flew from Los Angeles to New York in 18 hours and 21 minutes—breaking the former record by more than 36 minutes. Gerald F. Vultee, Lockheed Chief Engineer, said the NACA cowling "increased the speed of the aircraft from 157 to 177 miles per hour." He further stated that the record could not have been achieved without the NACA cowl, and gave the NACA credit "for painstaking and accurate research and [its] generous

20. For example, MacDonald Aircraft asked Weick to design a cowling for their "Doodlebug." Interview with F. E. Weick. Also see F. E. Weick, "Recent N.A.C.A. Cowling Developments," Aviation, XXVI (February 16, 1929), Aeronautical Engineering Section, XXIV-XXVII.
Publicity surrounding cowling development was so favorable that the NACA received the 1930 Collier Trophy, emblematic of superior achievement in aviation development. As could be expected, this praise benefited the agency when it requested funds for LMAL expansion.

Although the major cowling investigation was completed, Langley engineers continued research to improve the original concept. In 1935, for instance, they undertook an investigation to determine the value of a blower to supply cooling air. The quantity of air and pressure drop requirements for effective use of a blower showed that "1 to 4 percent of the brake horsepower of the engine [was] required for adequate cooling with an assumed blower efficiency of 100 percent." In 1938 Langley conducted an investigation to determine the


22. The trophy was presented to the NACA by President Hoover at the White House on June 3, 1930. This was the first of five Collier Trophies won by the NACA. New York Times, June 4, 1930, 12; NACA Executive Committee Minutes, June 24, 1930; interview with Edmund C. Buckley, August 18, 1966; U. S. House, Independent Offices Subcommittee, Hearings, 71st Cong., 3d Sess., 1931, 502.

factors which affected the pressure available for ground-cooling in front of air-cooled engine cowlings. This investigation pointed out that an engine cowling "should be located as close to the propeller as possible." LMAL researchers never lost interest in the results of their fundamental investigations as long as a possibility for improvement existed.

Despite the obvious benefits to be derived from use of the NACA cowling—especially as revealed by the Hawk's flight—some time lag occurred before the cowl was in general use. The coming of the depression and its unstable economic conditions made manufacturers wary of costly design changes for their airplanes. George W. Lewis stressed, however, that adoption of the cowling would in itself create a monetary saving. "You can take the same airplane [add a cowling]...and with the same power, get more speed; you can take the same airplane and using less power get the original high speed, and with less fuel consumption." Such considerations impressed the manufacturers and military aeronautical engineers. By the end of 1931,

the NACA claimed that "almost every radial air-cooled engine installation above 300 horsepower" included either the NACA cowling or the Townend Ring. The value to be derived from the NACA cowl was pointed out to Glenn L. Martin when his company changed from the Keystone to the B-10 bomber in the early 1930's. Pratt and Whitney, who built the engine for the new Martin bomber, used the Townend Ring because of contractual agreements. With the Ring, the bomber flew at 190 miles per hour and landed too fast (95 mph) for the airports then in existence. George W. Lewis told Martin to adapt the NACA cowling for his airplane. Once this had been accomplished, the maximum speed of the aircraft rose to 225 miles per hour and the necessary landing speed dropped to a tolerable 65 mph. With this improvement, the Air Service purchased many of the B-10 models and rescued the Martin Company from the financial predicament it had faced.

The NACA estimated the economic value of the cowling to be greater than the total agency appropriations prior to its discovery. In arriving at a figure

for the savings achieved by use of the cowl, the NACA gathered the figures for the following: actual hours flown, reduction in drag, horsepower required, reduction in initial cost of an engine of less horsepower, and reduction in the cost of airplane maintenance and operation resulting from the saving in weight. From this figure the NACA deducted the cost of installation and maintenance of the cowl.\(^29\) Using this method, the possible savings per year, for both military and commercial aviation was estimated at $5,299,300. Industry itself estimated the savings to American aviation during 1932 to be in excess of five million dollars.\(^30\) The intangible benefits to the Langley Laboratory in terms of increased status and good will, though impossible to estimate, were tremendous.

Development of the NACA cowl led directly to another investigation in the propeller research tunnel. Although the cowl had been constructed and adapted to a single-engine airplane, Weick and his associates assumed that it would prove equally beneficial on a

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multi-engine aircraft. Placing the cowl on a tri-motor Fokker airplane, however, resulted in no gain in efficiency or speed. Designers usually placed outside nacelles on a tri-motor airplane on struts which extended below and forward of the wing: the drag of this placement had never been taken into account. With the cowling attached, the space between the nacelle and the wing was a matter of inches which did not allow a smooth air flow.

At the fourth annual conference in May, 1929, Air Service Colonel Virginius E. Clark, along with many airplane manufacturers, suggested that the PRT be used to test the efficiency of various nacelle-wing combinations. Lewis submitted the proposal to the NACA Executive


32. Interviews with John F. Victory, June 21, 1967; and Smith J. DeFrance.


34. Interview with Fred E. Weick. Also, "whenever two or more objects are placed near one another and caused to move together through a fluid, the force acting on the combination of objects is, in general, different from the sum of the forces that would act on each object if moved through the fluid alone." Donald H. Wood, "Engine Nacelles and Propellers and Airplane Performance," S. A. E. Journal, 38 (April, 1936), 149.
Committee which, realizing the value of such an investigation, authorized the tests to be conducted. Fred E. Weick and Donald H. Wood were assigned the task of designing a program to accomplish the desired results. Prior to the testing of various nacelle-wing combinations, the forces on each were individually measured. The sum of the drag of the nacelle and wing, tested alone, was different than the drag of a combined test—the difference being called "interference drag." 

Weick and Wood planned a program to test the nacelle-propeller combinations in a systematic series of twenty-one different positions in relation to the wing. These included both above and below the wing and within the leading edge of the wing. Although the most advantageous position would be the one "which had the least projection of overall area," this was not always possible because of the necessity for propeller clearance. With this restriction in mind, the tests


37. Interview with Fred E. Weick.
began in late 1929 and were completed the following year. Results showed that the "best location of the nacelle...is with the thrust axis in line with the center line of the wing and with the propeller about 25 percent of the chord ahead of the leading edge" of the wing. Naturally the nacelle had to be attached to the wing as smoothly as possible, and efficiently cowled.\footnote{38}

To give American commercial interests the earliest opportunity to benefit from this investigation, the NACA, in 1930, transmitted the results confidentially to the Army, Navy, and industry. Not until 1932, "when the first American airplanes embodying the principles had been designed and actually constructed," were the test findings released to the general public.\footnote{39} As had been true with the cowling investigation, the NACA attempted to compute the economic value of the nacelle-position research on multi-engine aircraft. The factors considered included: actual hours flown, improvement in net efficiency, reduction in horsepower required at cruising speed, reduction in original engine cost due to smaller


\footnote{39. \textit{NACA 19th Annual Report}, 1933, 2.}
horsepower requirement, and reduction in maintenance and operating costs. Using these factors, the NACA estimated the annual savings at $1,998,300. The agency used this estimate to justify increased appropriation requests for other areas of its research.

Of equal importance to investigations on cowling and engine placement, was LMAL research in the area of wing design. These programs were not restricted to one wind tunnel or one specific problem. The laboratory continually conducted thorough tests on the action of the air in relation to lift, drag and efficiency of wings.

In judging the value of a particular wing, one must determine its lift coefficient. This mathematical factor gives an indication of the amount of load which an airfoil will lift into the air. A wing has a different lift coefficient for each angle of attack, although the lift coefficient of a particular wing is most often stated for straight-ahead flight through air of sea level density. Along with the improvements in wing design for which LMAL was responsible, theoretical considerations


41. Gray, Frontiers of Flight, 98-99; Munk, Principles of Aerodynamics, 11-12. Even during a level flight the wing of an airplane strikes the air at a slight angle, called the "angle of attack."
were not disregarded. The NACA published technical reports on wing section theory which aided all aircraft designers and researchers. 42

Langley conducted its early wing section research in free flight examinations. In the early 1920's, the agency borrowed a Sperry Messenger from the Air Service for these tests. The multiple manometer, developed by Fred Norton, could accurately measure the pressure at various points on a wing in flight. Researchers constructed substitute sets of wings of various camber (curvature) and thickness to test on the Messenger. Mounting the sets of wings and measuring the pressures on them produced some information though not enough to validate new shapes for airfoil design. 43

Not until the Variable Density Wind Tunnel at LMAL was completed in 1922 could anything approaching a systematic series of tests be conducted on a large number


of airfoil shapes. Even with the VDT, other priorities delayed airfoil research until near the end of the decade. Eastman N. Jacobs, who led research in the VDT, prepared an outline for the examination of a great number of wing sections of varying shapes to determine the most efficient one for any particular aircraft. He also devised a methodology for attaching a number to each airfoil to make it readily identifiable. Positive results could be achieved over a large "family" of airfoils, then compared with the performance of other wing sections being used in this period.

The Clark Y airfoil which was the most widely used in the early 1930's, was also examined along with the LMAL-designed sections. A complete study was made of both camber, or wing curvature, and wing thickness and

44. Interview with Edmund C. Buckley. The number of a section was determined by its characteristics. "Thus the N.A.C.A. 2315 airfoil has a maximum camber of 2 percent of the chord at a position 0.3 of the chord from the leading edge, and a maximum thickness of 15 percent of the chord." E. N. Jacobs, K. E. Wood and R. M. Pinkerton, "The Characteristics of 78 Related Airfoil Sections From Tests in the Variable-Density Wing Tunnel," Technical Report No. 460, NACA 19th Annual Report, 1933, 300.

45. During 1924, LMAL developed an excellent method for observation of air flow. A stream of smoke was discharged in advance of the object being tested and a photographic record made exactly delineating the air flow around the object in smoke trails. NACA 10th Annual Report, 1924, 16.
their influence on the amount of lift produced. By 1935, most of the tests had been completed and the results showed that the section designated the NACA 23012 was the most efficient design for a wing. It had a considerably greater lifting capacity than the Clark Y section and, by 1939, was extensively used throughout the world. LMAL research on airfoil design did not end with the development of the 23012. Work progressed, although with less intensity, toward increasing the amount of laminar (smooth) flow over a wing section to reduce drag. This eventually culminated in the discovery of the so-called low-drag wing shortly prior to World War II.

Eastman N. Jacobs continued throughout the late 30's to investigate the possibility of producing a

46. Gray, *Frontiers of Flight*, 99. A greater amount of lift would be economically beneficial as larger airplane loading could be accomplished.

low-drag wing. On the NACA 23012 wing section developed at Langley, laminar flow lasted for only about 15 percent of the wing chord. At this point air flow over the wing became turbulent, increasing skin frictional drag and reducing the maximum speed and overall efficiency of an aircraft. Jacobs and his research team, including H. Julian Allen, Ira H. Abbott, A. E. Von Doenhoff, and Robert Pinkerton, hoped to create a wing on which laminar flow would cover at least 50 percent of the chord. 48

With the completion of a low turbulence wind tunnel in 1938, 49 an effective aeronautical tool became available for low-drag investigations. Theoretical advancements had also been needed before the proposed experiments could be undertaken. Basing their assumptions on the work of German aerodynamicist Ludwig Prandtl, Jacobs and Allen concluded that it was necessary to reduce pressure on the upper portion of the wing as far to the rear of the leading edge as possible. Previously, theoretical developments allowed an engineer to determine probable pressure distribution after the shape of a wing


49. "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943, 4, NASA Historical Archives (NHA).
was known. In the low-drag wing investigations, this process was to be reversed; that is, determining the desired pressure distribution, and from that calculating the appropriate wing shape.\textsuperscript{50} H. J. Allen devised a method to accomplish this phenomena with respect to thin wings and Jacobs, utilizing Theodore Theodorsen's basic airfoil theory,\textsuperscript{51} extended the calculations to wings regardless of their thickness.\textsuperscript{52}

The new developments in theory, along with experiments in the low turbulence wind tunnel produced by 1939 a set of low-drag wings designated Series 0, 1, 2, 3, and 4. Exact results of the laminar flow investigations were not published until after World War II, but the NACA hinted at the findings in its \textit{Annual Report} for 1939.

Discovery during the past year of a new principle in airplane-wing design may prove of great importance. The transition from laminar to turbulent flow over a wing was so delayed as to reduce the profile drag, or basic air resistance, by approximately two-thirds. It is too early to appraise adequately the significance of this achievement. So far, its application is limited to small airplanes, but there are indications of its ultimate applicability to

\textsuperscript{50} Interview with H. Julian Allen.

\textsuperscript{51} Theodorsen, Technical Report No. 411.

\textsuperscript{52} Gray, \textit{Frontiers of Flight}, 106.

\textsuperscript{53} \textit{Ibid.}; interviews with Manley J. Hood, June 15, 1967; and H. Julian Allen.
larger airplanes through continued research. It should increase the range and greatly improve the economy of airplane operation.\textsuperscript{54}

Although commercial applications of the low-drag wing were not so extensive as the NACA hoped, the wing development did play a major role in aerial operations during World War II. The P-51 "Mustang," during the war, explicitly proved the value of this Langley Laboratory innovation.\textsuperscript{55}

Additional wing research, although limited to problems of stability and control, brought LMAL researchers to investigate modifications in flap\textsuperscript{56} designs. Requests for information on the aerodynamic effects of flaps resulted in tests in the 7- by 10-foot wind tunnel. These examinations revealed that the "division of the total lift between the split flaps and the wing was little affected by flap deflection in the ordinary flight range."\textsuperscript{57} The purpose of the research on flaps was, in part, to increase both the lift and drag of the airplane's wings to facilitate landing at steeper angles and slower speeds. Positive results would, of

\textsuperscript{54} NACA 25th Annual Report, 1939, 1.

\textsuperscript{55} Interview with John F. Victory, June 22, 1967.

\textsuperscript{56} Flaps are hinged surfaces attached to the trailing edge of wings which can be deflected downward.

\textsuperscript{57} NACA 19th Annual Report, 1933, 3.
course, "increase the safety of airplanes a great deal." 58 Later, investigations were conducted on multiple, slotted, and split flaps in larger sizes. The improvements in stability and control of aircraft by research on elevators, fins and rudders, ailerons as well as that described on flaps, proved to be immensely valuable in aerial combat during the war. 59

Other airfoil research included the investigations of lift and drag effects caused by various protuberances on the airfoil section. One example of this was the test conducted in the eight-foot high-speed wind tunnel in 1937 on the drag effects of rivet heads. Earlier studies 60 indicated an increase in drag produced by the rivet heads and other surface irregularities, and the 1937 project was designed to determine the drag effect of "rivet size, type and arrangement, lap type


and arrangement, and surface roughness." Results of the wind tunnel tests illustrated that as airfoils became more efficient, the percentage effect of the heretofore minor roughness on a wing became greater. Studies at LMAL recommended designing wings as smoothly as possible to increase the efficiency of the aircraft by reducing drag to a minimum.

In the realm of aircraft power plant research, generally the province of engine manufacturers, Langley engineers made a number of valuable studies, especially with regard to superchargers. As the altitude at which an aircraft could operate increased, the density of the air in which it operated, of course, decreased. In order to keep the engine from stalling, an external device was needed to compress the "thin" air and pump it into the engine. This action of increasing the mass of air over that which would normally be drawn into an engine through the pumping actions of the pistons is called supercharging.

62. Concurrently, tests were conducted at LMAL to measure the drag of all parts of an aircraft including landing gear, lapped joints and wing struts. NACA 22nd-24th Annual Reports, 1936-1938, passim.
An attempt to achieve engine power comparable to that at sea level, regardless of the altitude at which an airplane flew, occurred in 1922. Langley engineers attached a Roots type blower to a Liberty-12 engine for flight tests. Propeller difficulties prevented completion of this test, however, and delayed research until 1924 when an investigation was authorized "to determine the approximate adaptability of a supercharged air-cooled engine to conditions encountered in flight." 64 The Navy Department, most interested in all features of air-cooled engines, requested this study. Earlier investigations illustrated supercharging benefits on the water-cooled engine of a DH-4, with only "a slight sacrifice of low-altitude performance." 65

In 1927, investigators placed a NACA Roots type supercharger on a number of service training airplanes

64. NACA 8th Annual Report, 1922, 25-26; Research Authorization No. 119, August 19, 1924, LaRC Files. The possibility of supercharging from sea level and boosting engine power for use in bombing airplanes and obtaining a good rate of climb was being considered. Report of Chairman of NACA Committee on Power Plants for Aircraft to NACA, April 24, 1924, NHA.

equipped with standard Wright J air-cooled engines. Flights were conducted to determine the effect of the supercharger on the climb performance of the airplanes. In addition, instruments measured the cylinder-head temperatures and carburetor pressures and temperatures. The supercharger gearing allowed the engine to receive air at ground level pressure up to a height of 18,500 feet.

Beneficial aspects of the LMAL supercharger adaptation were clearly evident in the published results of these flights. Absolute ceiling of the aircraft, which had been 19,400 feet, was raised to 32,600 feet. Elapsed time in climbing to 16,000 feet fell from 32 to 16 minutes. Its value now scientifically established, the NACA supercharger soon came into general use.66

One of the few research projects at LMAL on a complete engine concept was a study of the possibility of the diesel engine for aircraft. The Packard Motor Car Company made early investigations of this type of engine for use in airplanes. Packard made its first flights, albeit with great secrecy, in 1928 when the company built an air-cooled radial engine with a fuel injection system.

based on the diesel principle. The first public exhibition of the engine built by the Packard Company occurred on May 14, 1929. A Packard-built diesel engine airplane flew from Detroit to Langley Field in about 6 hours and 50 minutes for a demonstration at the fourth annual LMAL conference. Fuel expended in the flight was said to have cost only $4.68, thereby pointing out the primary advantage of a diesel engine—very low fuel expense.

Following this performance, the Power Plant Division at Langley began research in an attempt to increase the power output of the diesel engine and to improve its fuel. Another major problem of the engine was the difficulty of maintaining satisfactory control at low or stalling speeds. However, after a number of years of research on diesel engines for aircraft, the NACA concluded that, in comparison with conventional engines, the diesel "requires a higher boost to obtain

the same take-off," and the poor weight to horsepower ratio made use of the engine for aviation impractical.\textsuperscript{71}

NACA carried out research on complete jet engines for aircraft after completion of the Engine Research Laboratory in 1943. Earlier background studies had been conducted by LMAL. Edgar Buckingham of the National Bureau of Standards discussed the possibility of jet propulsion for aircraft in a 1922 NACA technical report. His concept involved compressing air and mixing it with fuel in a combustion chamber. Thrust would then be produced by driving the combusted product through a nozzle.\textsuperscript{72} The weight of the engine and its rapid fuel consumption compelled Buckingham to conclude 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."\textsuperscript{73} Aircraft existing in the 1920's had too low a maximum velocity to make jet propulsion economically feasible.

\textsuperscript{71} NACA 25th Annual Report, 1939, 26. Some further investigation took place under NACA direction following the opening of the Lewis Engine Research Laboratory in 1943.


\textsuperscript{73} Ibid., 85.
From the publication of the Buckingham report, to the late 1930's, Langley carried out very little research on the possibility of a jet power plant for airplanes. Frank Whittle in England and German aeronautical engineers took greater interest in the concept. The Germans actually flew a turbo-jet powered aircraft on August 27, 1939. Also in 1939, LMAL engineers conducted a preliminary study to re-evaluate Buckingham's findings; its purpose was to determine their adaptability to aircraft capable of higher speeds than were available at the time of the 1922 report.

However, after the war in Europe began, and President Franklin Roosevelt called for the production of 50,000 American airplanes annually, the necessity for design freezes pre-empted the wartime production of an American jet. Vannevar Bush, NACA Chairman, in an effort to keep America from falling behind foreign developments, established a Special Committee on Jet Propulsion in March, 1941. To head the committee, Bush appointed 82-year-old Dr. William F. Durand of Stanford


University, one of the original members of the Advisory Committee. This committee, in its first resolution, recommended that Eastman N. Jacobs at Langley construct a non-flying jet model. Jacobs, in his spare time, had studied the problems of jet propulsion. Durand also encouraged three companies, General Electric, Westinghouse and Allis-Chalmers, to develop designs for a jet propulsion unit.

The first flight of a jet aircraft in the United States occurred in 1942. General Electric built the engine based on the research accomplished by Whittle. The company adapted its IA engine to a service test model of the Bell Aircraft XP-59 which flew for the first time on October 1, 1942. Shortly after this flight, Army Air Corps General Henry H. Arnold requested a secret demonstration of this aircraft at LMAL. Operational characteristics of the airplane, however, were not sufficient for immediate use. Although the


77. W. F. Durand to NACA Executive Committee, April 23, 1941; NACA Minutes, April 24, 1941; New York Times, April 3, 1945, 16.

Engine Research Laboratory staff conducted much research, no United States jet aircraft took part in wartime activities. The foundation had been set, however, for eventual LMAL and NACA projects which evolved in the immediate post-war period.

One significant aeronautical innovation, although developed at Langley by laboratory personnel, was not formally connected with "official" research. This was the construction and adaptation in the mid-1930's, of the tricycle landing gear for aircraft. Once again the leading figure in this research was Fred E. Weick, of cowling and engine placement fame.

Earlier investigations of landing gear drag by William H. Herrnstein and David Bierman in the LMAL 7- by 10-foot and 20-foot wind tunnels had advanced knowledge to the realization that retractable landing gear offered great benefits. With the reduction of engine and wing drag as a result of prior investigations, landing gear drag gained greater importance in achieving increased aircraft efficiency. Herrnstein and Bierman

found that although encasing the landing gear in fairings would somewhat reduce drag, "low-drag or retractable gears...result in a substantial increase in high speed or saving in power at the same speed." Following publication of these results, manufacturers soon began work adapting retractable landing gear to their aircraft.

During the period in which Bierman and Herrnstein conducted their drag research, Weick and his associates began considering a new type of landing gear. Organization of the group evolved in a rather unusual manner. Weick, while Assistant Chief of the Aerodynamics Division, additionally took charge of the Atmospheric Wind Tunnel Section following the resignation of the section leader. To create greater interest in flying among the group, Weick started a seminar-type arrangement with the men to discuss various aspects of private flight. At the time, the Department of Commerce was quite interested in private flying and solicited designs


for an aircraft suitable to general use. The men in Weick's "seminar" decided to construct an airplane, during leisure time, using the features they discussed—including the tricycle landing gear. 82

Most aircraft which had two wheels forward of the center of gravity and a third stationary wheel below the tail often experienced problems of nosing over, ground looping and difficulty in landing smoothly. The group hoped to achieve the following: safe landing regardless of whether or not the flight path was leveled off at contact, safe landing at up to twice the minimum speed, easy steering gear absolutely free of ground looping, drift landings possible with no excessive side force on landing gear structure, and elimination of nosing over regardless where the airplane landed. 83

As eventually placed on the W-l airplane, the landing gear had two wheels behind the center of gravity and a steerable wheel below its nose. The front wheel was in a fork angled to the rear as on a bicycle. Upon completion of the W-l, the Department of Commerce requested that LMAL conduct flight tests on the aircraft.


Langley test pilots William H. McAvoy and Melvin N. Gough, after flying the W-1, reported a problem of shimmying in the castering wheel. Designers overcame this difficulty by allowing the wheel a slight lateral freedom. The new style of landing gear was a great improvement over aircraft with a conventional gear (tail wheel). Industry never produced the W-1, but by 1938 most manufacturers began adopting the tricycle landing gear in their own aircraft.  

Another aeronautical problem on which Langley personnel began research, only to see it transferred to another laboratory, was that of aircraft icing. Ice formation on wings can rapidly alter the aerodynamic characteristics of an airplane resulting in extreme danger to its occupants. In general, three methods exist for removing ice: mechanical, chemical and thermal. Langley research teams investigated various techniques involving all these methods.


85. An example of the mechanical method would be hacking the ice off; chemical would involve a spray to prevent ice formation; and thermal would involve heating a surface for ice prevention.
At the request of Admiral William A. Moffett, Chief of the Bureau of Aeronautics of the Navy Department, the NACA Executive Committee authorized research in June, 1928, for an investigation to determine the conditions under which ice forms on structures of aircraft and to develop possible means of preventing ice formation. In order to study icing problems, LMAL constructed a 6-inch wind tunnel with equipment to refrigerate the air. This was the "first icing research tunnel" in the world. Theodore Theodorsen and William C. Clay directed most of the thermal anti-icing research at LMAL during this period. In 1936, Lewis A. Rodert joined the Langley staff, took an immediate interest in icing problems, and later received the Collier Trophy for his investigations.

At the 1930 annual conference, the B. F. Goodrich Rubber Company demonstrated its mechanical de-icer in the Langley 6-inch wind tunnel. A flexible rubber covering fit over the leading edge of a wing model and, when moisture cooled on it, ice formed on the wing.

switch inflated the rubber "boot" changing the contour of the wing; the ice broke, and the airstream blew it away. A mechanical device of this type appeared promising, but further tests disclosed that the ice could not be completely removed in this manner. Therefore other projects were proposed to overcome icing. LMAL engineers also conducted studies on the effectiveness of chemical ice prevention. They discovered that a mixture of alcohol and glycerin was most beneficial, although only during moderate icing conditions.  

Most of the ice prevention research at Langley was in the area of thermal de-icing. The investigators attempted, in various ways, to introduce heat into the wings. One of the first designs tested was a gas boiler which piped steam to the interior of the wings, but its weight of seventy pounds made its use prohibitive. George Lewis said that electric heat was also too expensive in terms of weight because of the size of


90. *NACA 15th Annual Report, 1929*, 82; *NACA 22nd Annual Report, 1936*, 16. LMAL research showed that "ice is inclined not to form between the temperatures of 0° to 28°, but between 28° and 32° the situation was quite dangerous." U. S. House, Independent Offices Subcommittee, *Hearings*, 72d Cong., 1st Sess., 1932, 322.

batteries or generators which the airplane would have to carry. Also, as a heating unit would need to be installed inside the wing of an airplane, the stability of the wing structure had to be ensured.  

In order to conduct more extensive investigation of icing problems, a larger refrigerated wind tunnel was built in 1938. To save money, laboratory personnel secured many of the materials used to build the tunnel from the Army. Steel trusses and columns that had been associated with buildings torn down at Fort Eustis, Virginia, were "borrowed" by Langley. Insulation for the tunnel consisted of kapok removed from surplus life preservers donated by the Navy. W. Kemble Johnson directed the construction and, as laborers, hired unemployed Hamptonians regardless of their previous occupations. With these methods, the cost of the entire tunnel was held to approximately $100,000.


93. The tunnel was used for icing research only about six months. It was then converted to a low turbulence tunnel to conduct low-drag airfoil studies. "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943, 4.

94. To remove the kapok from life preservers, Johnson recalls hiring about half of the Hampton High School football team. Other laborers included golf
With the tunnel completed Rodert, now directing the research, devised a method of using exhaust heat to prevent ice formation. The exhaust from one cylinder of a nine-cylinder engine was piped to a condenser in the leading edge of the wing. Later extensions of this process distributed heat over the entire wing chord. The relative simplicity of the method kept the added weight to a minimum. With the opening of the Ames Laboratory, Rodert and his associates shifted their activities to the West Coast. During the war, Rodert's group built thermal anti-icing systems for, among others, the Consolidated B-24 Liberator, the Boeing B-17 Flying Fortress, and the North American B-25. Although the NACA received its greatest publicity for ice prevention research at the Ames Laboratory, the background investigations at LMAL made these later successes possible.

Other research of equal import, if less public note, continued to progress. Researchers not only conducted examinations on airships and seaplanes, but also developed background studies on helicopters. Airship professionals, businessmen, and other local people in need of work. Interview with W. Kemble Johnson, June 27, 1967.

study consisted primarily of a complete pressure distribution test on the Los Angeles. The limited value of this type of craft, along with limited amounts of available funds, convinced the NACA to restrict research activities in this area to a minimum. On the other hand, LMAL tested early models of the autogyro, tail-less airplane, and helicopter. Once again, however, the crush of other activities forced these investigations to a secondary status until after the war. Seaplane tests, conducted in the NACA Tank, primarily concentrated on improvements in the shapes and strengths of floats and hulls. Drag resistance of water was roughly comparable to air resistance once the craft had taken off. The Clipper flying boats used before the war for transport purposes to South America and the Pacific area were designed on the basis of numerous investigations at Langley. As previously noted, extensive construction of landing areas during World War II made further seaplane development of slight value.


97. Research Authorization No. 166, November 10, 1925, LaRC Files; U. S. House, Independent Offices Subcommittee, Hearings, 74th Cong., 2d Sess., 1936, 39. A good outline of LMAL hydrodynamics research is in Gray, Frontiers of Flight, 63-75. Langley later also investigated submarines for the Navy in an attempt to
To increase the safety of flying, the Langley staff investigated ideas in the area of airplane stability and control. Effective stability implied the ability of an aircraft to return to an equilibrium position following a disturbance: for instance, an airplane may have difficulty recovering from a spin. Investigation of this phenomena in the LMAL spin tunnels pointed out the importance of the size of the tail surfaces in recovery. Spin tests continued and played a major role in aerial operations later during the war.

Other than the spin tests, little scientific knowledge was available concerning aircraft stability until 1937. Prior to that time flying quality evaluations were based on pilot reactions. Following a flight, a pilot might say that a particular airplane was easy or difficult to control—obviously an unsatisfactory method to reduce underwater drag. Interview with Floyd L. Thompson, January 16, 1968. During the war, forced landings of an aircraft at sea were studied by LMAL. See Chapter VIII.

98. At the 1930 Annual Conference, W. B. Stout of the Ford Company said that controls were much too complicated and made flying more difficult than it needed to be. New York Times, May 14, 1930, 2. The call to make flying easier, however, was repeated again in 1939 by one of the LMAL test pilots. See Melvin N. Gough, "The Test Pilot Looks at Aircraft Safety," Aviation, 38 (May, 1939), 20.

for drawing conclusions about an aircraft.\textsuperscript{100} In 1937, first under the direction of Hartley A. Soule, and later Robert R. Gilruth, a project began to "put in qualitative terms those qualities of an airplane that make it good to fly." At the suggestion of Edward P. Warner, MIT aerodynamicist, the laboratory "prepared a general program of measurable flying qualities."\textsuperscript{101} Once it had been determined what flying qualities were applicable to measurement, the Instrument Research Division accepted the task of building the equipment to make the readings in free flight.\textsuperscript{102}

By March, 1941, examinations had been completed on sixteen airplanes; Gilruth produced a report summarizing the tests and outlining optimum features for efficient handling qualities and the reasons for these requirements.\textsuperscript{103} The report was immediately sent to the

\begin{itemize}
  \item \textsuperscript{100} Interview with Robert R. Gilruth, June 26, 1967.
  \item \textsuperscript{101} Melvin N. Gough, \textit{Aviation}, 38 (May, 1939), 20.
British, but security measures prevented its publication until after the war. The British detailed a technical mission to confer with Gilruth, and both British and American aircraft designers incorporated much of the criteria in the report. To allow more extensive research on stability problems, LMAL completed a stability wind tunnel in 1942. In this tunnel a model could be subjected to curving or rotating air flows in order to "simulate those actually encountered when an airplane rolls, pitches or yaws." With the tunnel more rapid and less expensive examinations were possible which aided the American war effort.

The period from 1927 to 1939 was one of tremendous advancement in the knowledge of all aspects of flight. A considerable amount of this advancement can be traced directly to research accomplished at the Langley Laboratory. Although the information gathered can not be classified as entirely fundamental, laboratory officials were satisfied with their results. Elton W. Qualities Based on Flight Tests of Numerous Airplanes," Technical Report No. 715, NACA 27th Annual Report, 1941, 201-07.

104. Interview with Robert R. Gilruth.

Miller, Chief of the Aerodynamics Research Division, said "it is deemed to be not the purpose of [LMAL] to devote itself to fundamental research as distinguished from that which has a definite practical object. It is the aim of the Laboratory," Miller continued, "to apply scientific methods to the solution of the practical problems of aerodynamics." The great value of the solutions uncovered at LMAL was clearly illustrated by American air power during the Second World War.

106. Elton W. Miller to H. J. E. Reid, December 19, 1930, LaRC Files.
CHAPTER VIII

WARTIME AT LANGLEY

Long before December 7, 1941, or for that matter before September 1, 1939, preparations were made by the NACA and its Langley Laboratory for eventual United States participation in another world conflict. Of course there could be no assurance that war would come but, after 1933, the saber-rattling of Hitler came to put the rest of the world on guard and, albeit belatedly, forced Americans to give greater consideration to problems of national defense. All activities related to preparedness for war had to be taken surreptitiously, because isolationist feeling in the United States, as evidenced by the neutrality legislation of the 1930's, was very strong.

The earliest joint activities of the military and the NACA in preparing for possible involvement in hostilities occurred in 1936. Major General Oscar Westover, Chief of the Army Air Corps, called a meeting of the joint Army-Navy Aeronautical Board, of which he was chairman, to discuss the role the NACA would play should the United States become involved in a war. To promote NACA-military cooperation, the Board decided that the NACA should be under its direction in the event
of war.¹ For its part, the NACA also wanted to study its own role in case of war. On December 22, 1936, NACA Chairman Joseph S. Ames appointed a Special Subcommittee on the Relation of the NACA to National Defense in Time of War under the chairmanship of Major General Westover.² Not surprisingly, when this committee reported, it also recommended that, in the event of war, the NACA become an adjunct of the Aeronautical Board.³

NACA Director of Aeronautical Research George W. Lewis viewed firsthand the advanced aeronautical research being conducted in Germany and Russia. In September and October, 1936, he toured all the research facilities in the two countries and was especially impressed by the German activities. Most of the aeronautical research projects being conducted in Germany during his tour were at the Deutsche Versuchsanstalt fur Luftfahrt (DVL) at Adlershof near Berlin. Lewis reported, however, that many other aeronautical research centers were "completely equipped with every conceivable device and facility, but

¹"Some Effects of the War on the NACA," May 28, 1942, NASA Historical Archives (NHA).

²NACA Minutes, October 22, 1936; NACA Executive Committee Minutes, February 11, 1937.

the employees had not yet reported for duty." He estimated that over 1,000 employees would soon be at work on aeronautical and engine research in Germany, and bemoaned the fact that Langley had a staff of only 350. In addition, Lewis believed that German manufacturers were "turning out as many airplanes as possible, and the research and development organizations...[were]...working on problems that have an immediate bearing on this production program." Just as the Zahm-Hunsaker trip of 1913 aided in the founding of the NACA, the 1936 tour made by Lewis gave the agency information to justify requests for expansion. Dr. Ames reported to Congress that, because research activities in Europe had been expanded, United States supremacy in available research facilities was "seriously threatened."

During 1937, although both the budget request for research and number of employees was increased by the

4. George W. Lewis, "Report on Trip to Germany and Russia, September-October, 1936," 13, NHA.

5. Ibid., 17-18. Lewis reported on his trip to LMAEL employees in an address at the laboratory, telling them to be ready for any eventuality. Interview with W. Kemble Johnson, June 27, 1967.

6. See Chapter II.

pressure of greater work loads, few direct preparedness measures were undertaken. The laboratory tightened security regulations so that foreigners, when taken there, saw only the laboratory's exterior. At the Headquarters of the agency, emphasis in public statements began to shift to military rather than commercial aviation. For instance, the 1937 Annual Report stated that the "safety and security of our country...[and]...retaining our present superiority in technical development...will depend largely on the ability of this organization to solve... fundamental problems." The NACA was ready to assume its rightful place if war came.

In an increasingly tense world situation in 1938, apprehension was heightened by estimates that Germany had 6,000 first-line combat airplanes and 3,000 more in

8. The research budget request in 1937 was $1.97 million compared with $1.02 million in 1936. The number of employees at LMAL rose from 341 in 1936 to 402 in 1937. "NACA Budget Requests, and Appropriations," NASA Budget Office; "Growth of Langley's Staff: Professional, Non-Professional and Total," June 30, 1959, NHA.

9. This was announced in June, 1937—although in July, five members of the Japanese Imperial Army made an inspection tour of LMAL. Newport News Daily Press, June 9, July 21, 1937.

The NACA gained further information on German developments as a result of the visits of Charles A. Lindbergh, a member of the NACA, to the German aeronautical centers. Lindbergh kept his American compatriots informed about German activities through letters to NACA Chairman Joseph S. Ames. He pleaded for the United States to "increase our own rate of development...[else]...Germany continue to be the leading country in the world" in terms of aircraft production. Germany was "far ahead" of the United States, Lindbergh said, "in military aviation." Although he felt that America had a time advantage because of geographical location, Lindbergh contended that the United States must "lead in the quality of design...[rather]...than in quantity of service aircraft." America could afford to devote time to "research and development of prototypes," instead of rushing production of existing designs.

The messages of Lindbergh influenced the NACA. Ames said that "the progress of aeronautics in Europe, especially in the field of military aircraft development,


12. Charles A. Lindbergh to J. S. Ames, November 4, 1938, NHA.

13. Lindbergh to Ames, November 28, 1938, NHA.
...

[caused]...deep concern in this country." In the realization that its research was essential to national defense, the NACA Executive Committee, in December, 1938, resolved to close its laboratories to all non-official visitors "until further notice because of the threat of war." Ames also wrote to President Roosevelt saying that "in the development of air strength for national defense, a definite advantage will lie with that nation that has the most efficient aircraft." Again, this assertion added justification for expansion requests by the agency.

Events in 1939, prior to the outbreak of war in Europe on September 1, stimulated planning for hostilities. The NACA openly began to warn about the possibility of war, and laboratory employees felt a sense of urgency in their work. Preparations by the Army Air Corps

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14. Ames to Lindbergh, December 22, 1938, NHA.

15. NACA Executive Committee Minutes, December 16, 1938.


included the detailing, on March 18, 1939, of Major Carl F. Green to Langley Field to represent the Material Division at LMAL. Green acted as a liaison between the Air Corps Material Division and the NACA. General Henry H. Arnold of the Air Corps remarked that this action was necessary to the establishment of a much closer relationship between the Material Division at Wright Field, Ohio, and the Langley Laboratory. The appointment of Major (later Colonel) Green promoted extremely close cooperation which was essential to the subsequent war effort. Another military proposal affecting the NACA was a suggestion by the Secretary of War and Acting Secretary of the Navy that the NACA be assigned a definite place in the National Mobilization Plan. In this way, if war broke out, the NACA would be in direct contact with the policies of the National Mobilization Board. As plans for war evolved, however, a separate establishment was formed to direct NACA's wartime activities.

Shortly prior to Hitler's invasion of Poland, George Lewis made a second inspection tour of the German aeronautical laboratories. He had planned a trip to

18. NACA Executive Committee Minutes, June 23, 1939.

19. Harry H. Woodring and William D. Leahy to Franklin D. Roosevelt, June 22, 1939, NHA.
deliver the Wilbur Wright Memorial Lecture in London. As a consequence of his earlier hospitality to German representatives in the United States, he was invited to visit research centers in Germany. After consultation with the Departments of State and War, Lewis decided to accept the invitation to visit Germany while he was in Europe. During his six-day stay in Germany, June 6-11, 1939, his hosts allowed him to go almost wherever he wished. Lewis toured not only the German research centers, but the aircraft production companies as well. The trip further convinced him of Germany's readiness for war, and the need for the United States to expand its research facilities. Vannevar Bush, who had become Chairman of the NACA upon the retirement of Joseph S. Ames, cited the Lewis findings and pressure of military investigations in testimony before the House Independent Offices Subcommittee. "Pressure is being exerted on all sides to push many investigations," Bush declared, "in order that the answers might be obtained immediately for use in present military designs." The rush lessened efficiency


21. *Ibid.*; "Itinerary of Dr. Lewis' Visit to Europe, May 17 to June 23, 1939," NHA.
and this handicap would not be overcome if the agency was "retarded by lack of personnel." 22

As the United States began to prepare for eventual war, increased secrecy was evident throughout the activities of the NACA. Beginning in 1940, the Annual Reports of the NACA did not "disclose the full scope of the Committee's work." This condition of secrecy was a response to the organization of LMAL activities "to answer primarily the research needs of the military services." 23 Because of the pressure of military problems, Dr. Bush said that the laboratory was forced "to postpone a good deal of... [its]...long-range research." 24 On the assumption that the United States would enter the war, the NACA budget request for fiscal year 1941 asked for almost a 100 percent increase in appropriations over the 1940 request. Congress, however,


23. The research being conducted is discussed more specifically below. Vannevar Bush to Franklin D. Roosevelt, December 27, 1940, submitting NACA 26th Annual Report, 1940, v.

did not grant so large an increase until the following year.  

To further consolidate and coordinate aeronautical research and production in the United States, the NACA appointed S. Paul Johnston, editor of Aviation magazine, Coordinator of Research to assist Director of Aeronautical Research George W. Lewis. Coordination of aeronautical activities throughout the country was necessitated by President Roosevelt's call on May 16, 1940, for the production of 50,000 airplanes annually by the United States aviation industry—ten times the normal output. This request affected the NACA Headquarters and laboratory staff with the President's acknowledgment of the need for immediate aeronautical developments. Johnston, as Coordinator of Research, kept the NACA informed of aeronautical activities throughout the country by "visits to and consultation and correspondence with: aircraft and allied industries, governmental agencies concerned, and scientific and educational institutions." In this

25. The 1941 budget requested $14 million but only $6.4 million was appropriated. In 1942, however, the appropriation was $19.86 million. Interview with W. Kemble Johnson; "NACA Budget Requests, and Appropriations," NASA Budget Office.

manner, the NACA and its laboratories assisted in the desire for the "great expansion in aircraft production." By 1942, when production quotas were being met, Johnston left for employment in industry and his NACA position was not filled.  

At the suggestion of NACA Chairman Bush, President Roosevelt established, through the Council of National Defense on June 27, 1940, the National Defense Research Committee (NDRC). John F. Victory, Secretary of the NACA, suggested both the name and organizational pattern of this committee. For this reason, the NDRC closely resembled the NACA structure. It had an appointed, unpaid advisory committee at the top and various technical subcommittees to deal with individual problems. Victory, in designing the structure of the NDRC, pre-empted for the NACA the direction of "scientific research on the problems of flight." Roosevelt designated Bush as


28. See Irvin Stewart, Organizing Scientific Research For War (Boston: Little, Brown and Company, 1948), 7-14; Vannevar Bush, Science: The Endless
Chairman of the NDRC, while Bush also remained as NACA Chairman.

In February, 1941, the two committees signed a "memorandum of agreement" defining the exact area of interest of each. The NDRC agreed to work on aeronautics only in areas where the NACA did not conduct research. But within a year it became obvious that the NDRC lacked a wide enough scope to handle the problems which arose. To fill the gap between research on a military problem and procurement of a developed product and, to establish formal machinery for correlation of research with the NACA, Roosevelt, on June 28, 1941, established the Office of Scientific Research and Development (OSRD)—again with the NACA organizational structure. Bush was named Director of the OSRD.29 He resigned as Chairman of the NACA and Jerome C. Hunsaker replaced him.30 OSRD, while assigning research on aircraft to the NACA, assisted the Advisory Committee with studies on airplane accidents


29. Stewart, Organizing Scientific Research For War, 35; U. S. President, 1933-45 (Roosevelt), Establishing the Office of Scientific Research and Development in the Executive Office of the President, Executive Order No. 8807, June 28, 1941.

30. NACA Executive Committee Minutes, June 24, 1941.
and sound control. Throughout the war cooperation between the OSRD and the NACA remained at a high level and was mutually beneficial.

By this time, the Langley Laboratory expended most of its energy on investigations of a military nature. Although some fundamental research continued, George Lewis said, "our major effort...[was]...on applied military production types." Of course, by 1941, personnel and equipment at LMAL had increased substantially in order to allow expanded and more rapid investigations. To fully understand how this buildup came about, it is necessary to review earlier events.

Beginning in 1936, the NACA annually asked for increased funds to improve and expand the Langley Laboratory. To justify expansion, NACA officials quite often cited the expansion of aeronautical research centers throughout Europe. "Superior research facilities recently constructed in England, France, Germany and Italy will," NACA officials declared during the 1936 appropriation hearings, "within a few years enable European countries to surpass the United States in the technical development

31. Baxter, Scientists Against Time, 188.

of aircraft." With the exception of 1938, funds appropriated to the Committee rose annually throughout the wartime period. Until the United States actually entered the war, this increase was relatively slow; but, from a $6.40 million appropriation for 1941, it jumped to $19.86 million for 1942.

Much of the additional funds were expended in expanding the Langley physical plant. The area of Langley Field assigned to the NACA grew in 1939 with a War Department grant of additional land. This began what is today the "West Area" of the Langley Laboratory, approximately two miles from the original site. The first building in the new area was a structures research laboratory, made possible by a $6,723,000 Congressional grant. There was little question that, as the tempo of research increased, new facilities for research at LMAL would be needed. During 1940, Congress

35. NACA Executive Committee Minutes, November 16, 1939.
37. See the testimony of John F. Victory in U. S. House, Deficiency Appropriations Subcommittee, Hearings, 76th Cong., 1st Sess., 1939, 36; and George W. Lewis in
appropriated funds for construction at LMAL of a stability wind tunnel, a 16-foot high-speed wind tunnel, and a second seaplane towing tank.\footnote{38}

Acquisition of additional land by the Army in 1941 allowed this service to grant another seven acres to LMAL for expansion. The majority of the new wartime facilities were constructed on the West Area of Langley Field.\footnote{39} In expanding so rapidly, earlier problems of insufficient electric power were overcome by construction of an electric power generating plant at the laboratory itself. In requesting funds to build the power generating plant, Vannevar Bush asserted that the "increasing load imposed upon us by the Army and Navy...forces us...to go to a 24-hour operation" of the LMAL wind tunnels. The power required was too demanding for the local power


\footnote{38} These projects were, of course, not completed until some time later. \textit{NACA 26th Annual Report, 1940}, 19-20, 28. Also see "Wind Tunnels and Other Research Equipment (at the) Langley Memorial Aeronautical Laboratory," November 15, 1943, 4-5; and \textit{NACA 32nd Annual Report, 1946}, 40, which summarized construction at LMAL during the war.

\footnote{39} Today the entire administration, and most of the research conducted at the Langley Research Center is in the West Area. Interview with Floyd L. Thompson. U. S. House, Deficiency Appropriations Subcommittee, Hearings, 77th Cong., 1st Sess., \textit{1941}, 100-01.
company and Langley could expand only by producing at least a portion of its own electricity.  

Construction throughout the wartime period brought the number of wind tunnels at Langley to a total of fourteen. In 1947, these included a: 300 mph 7- by 10-foot, high-speed 7- by 10-foot, 9-inch supersonic, 16-foot high-speed, 4-foot supersonic, two-dimensional low turbulence, rectangular high-speed, two-dimensional low turbulence pressure, propeller research, 8-foot high-speed, full-scale, 19-foot pressure, spin, and a free flight tunnel. Of course, by 1947, the NACA had two other laboratories which housed many research facilities.

Concurrently with the increasing amount of research facilities and speed-up in work accomplished, staff requirements rose at LMAL. Due to a lack of personnel in 1939, George Lewis testified that of the projects authorized at Langley 49 were receiving no attention. He quoted H. J. E. Reid as saying: "We have

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right now work that would keep us busy for 2½ years."\textsuperscript{42} Congress allowed funds for relatively small personnel growth in the later 1930's, but became extremely generous once the United States entered the war.\textsuperscript{43}

When plans were approved in 1941, "for the operation of the Langley Field laboratory generally on a two-shift basis and in some sections on a three-shift basis," the difficulty of hiring qualified people was intensified.\textsuperscript{44} LMAL employees Tom Hawksher and Eugene Hickson devised a manner for maintaining a fairly complete staff of non-professional employees during the war years. In 1941 an "apprentice system" began at Langley to train men in ten different trades as they learned to be machinists, sheetmetal workers, aircraft mechanics, draftsmen, metal modelmakers or aviation metalsmiths. Entrants into the program were younger LMAL employees who had previously lacked a particular skill. Journeymen mechanics at the laboratory, with a natural resistance to younger tradesmen, "were mollified with


\textsuperscript{43} "Growth of Langley's Staff--Professional, Non-Professional and Total," June 30, 1959, NHA.

\textsuperscript{44} Interview with W. Kemble Johnson; \textit{NACA 27th Annual Report}, 1941, 8.
the apprentice system," since the more experienced workers became class instructors.  

This system of "on the job training" reduced the hardships which selective service occasioned LMAL.

Women were also employed to meet increased personnel needs. In March, 1942, the NACA announced that girls between 16 and 25 who were experienced modelplane builders would be employed by LMAL at a starting salary of $1,260. These women worked on aircraft instruments and balancing and testing of airplane models in the laboratory's wind tunnels.  

Later that year, the laboratory announced that women would be hired for "vital war work" in positions formerly held only by men. By June, 1943, Langley employed nearly 200 women. The Structures Division, which operated its own training school, assigned women to take simple strain gage readings.

45. Public Information Office Files, Langley Research Center (LaRC); interview with Caldwell C. Johnson, June 26, 1967.


48. Interview with Joseph N. Kotanchik.
Although "efficiency went down markedly" during the buildup in staff, the increase was necessary because, as NACA Chairman Jerome C. Hunsaker said in 1943, the "work load has been growing in volume and pressure." At the close of the war, when this pressure decreased, the staff at LMAL was reduced to approximately 2,700. Even so Langley was no longer the small, intimate organization it had been in the pre-war years.

At the same time that Langley expanded both its facilities and its personnel, plans were afoot for a second NACA laboratory. The agency justified development of another laboratory with four arguments: a limited amount of power was available in the LMAL geographic area, available land at Langley Field was becoming severely limited, congestion made LMAL less efficient, and an obvious defense hazard existed with all research facilities at a single location. Seldom openly stated,


50. "NACA Asks Congress For More Research Funds," Aero Digest, 43 (December, 1943), 328; "Growth of Langley's Staff--Professional, Non-Professional and Total," June 30, 1959, NHA.

but also a major factor in the desire for a second NACA laboratory, was the knowledge that by the late 1930's, approximately 60 percent of the American aircraft industry had come to be located on the West Coast. This geographical separation made rapid communications between the agency and its industrial counterpart very difficult.  

With this form of expansion in mind, although before any specific decision had been reached, the NACA, on March 3, 1936, established a Special Committee on Aeronautical Research Facilities with Rear Admiral Ernest J. King as chairman. The committee which had the task of surveying the aeronautical research capabilities of the United States, reported them inadequate to the country's needs. In December, therefore, as previously noted, NACA Chairman Ames appointed a Special Subcommittee on the Relation of the NACA to National Defense in Time of War headed by Major General Oscar Westover. Following a two-year study, the Westover Committee produced a report suggesting, among other things, the


54. NACA Executive Committee Minutes, February 11, 1937.
building of a new research center somewhere in the interior of the country or on the West Coast. 55 Ames appointed a Special Committee on Future Research Facilities on October 24, 1938, and named Rear Admiral Arthur B. Cook, Chief of the Naval Bureau of Aeronautics as chairman. 56

This committee inspected 54 sites as possible locations for a second NACA laboratory. Langley personnel met with the site selection committee to explain technical requirements for a new center. On December 30, 1938, the committee submitted a report recommending the establishment of a second research station at Sunnyvale, California, on Moffett Field, a former Naval airship base, approximately 38 miles south of San Francisco. 57

With this recommendation, supplemental estimates submitted to Congress by the Roosevelt Administration on February 3, 1939, included a request for $10,000,000 to

55. Ibid., August 19, 1938.

56. The committee also included Major General Henry H. Arnold, Edward Noble, Edward P. Warner and George W. Lewis. NACA Executive Committee Minutes, October 24, 1938.

build a NACA research station at Sunnyvale. Despite testimony by George Lewis, John Victory and Vannevar Bush before both the Senate and House Deficiency Appropriations Subcommittees, both houses of Congress rejected the original plea for funds. Even Major General Henry H. Arnold, Chief of the Army Air Corps, and Admiral Cook of the Bureau of Aeronautics could not provide enough pressure to secure the appropriation. One aeronautical journal, after a joint Senate-House Conference Committee excluded the Sunnyvale appropriation in April, 1939, said the cause was political because the district which would benefit was represented by a Republican, and Senators Millard Tydings of Maryland and Carter Glass of Virginia wanted any additional funds allotted to the East.

When a Third Deficiency Appropriation Bill was submitted, the NACA again requested funds for a new


laboratory. In order to overcome regional jealousies, no specific site for the center was stated. In addition, Robert H. Hinckley, Chairman of the Civil Aeronautics Authority, publically supported the NACA request saying that much more aeronautical research must be done, far more than the overburdened facilities at LMAL could sustain. This slight diversionary tactic succeeded and, on August 9, 1939, Congress authorized a $2,000,000 appropriation for construction of a second NACA research laboratory at a site to be selected. As expected, on September 22, the NACA announced its decision to locate the new laboratory at the previously noted site in Sunnyvale, California. The findings of a special site selection committee headed by Charles A. Lindbergh recommended Sunnyvale.

During the time NACA Headquarters fought for the Congressional appropriation, Langley personnel, who assumed eventual success in gaining funds, designed plans for the new laboratory. Lewis and Henry J. E. Reid, LMAL Engineer-in-Charge, felt that Smith J. DeFrance, who


directed most new tunnel construction at Langley, had the most experience needed to formulate plans for a second research center. Prior to the final decision on location, DeFrance organized a group of his fellow employees at LMAL to design equipment for the new facility. The decision to utilize Langley employees for future planning proved extremely wise. No group was more knowledgeable in the needs of a research laboratory than men who had worked at one for many years. DeFrance, for example, had served as a research engineer at LMAL since 1922.

The DeFrance-led group at Langley included aerodynamicists, structural engineers, and draftsmen. These men completed the preliminary designs for wind tunnels and other research equipment before Congress granted authorization for the laboratory. Although DeFrance directed the background planning, not until the spring of 1940, did the NACA officially name him as Engineer-in-Charge. To coordinate plans for the various sections of the new laboratory, DeFrance named George F. Bulifant to draw up a proposal for a mechanical

63. Interviews with John F. Parsons, June 16, 1967; and Smith J. DeFrance.

64. Interview with Smith J. DeFrance.
shop, Manley J. Hood to design specific aeronautical tools, and Howard W. Kirschbaum to plan an instrumentation and photography division. These three men were representative of the many who took part in the careful planning conducted before any employees left LMAL for reassignment.

With preliminary plans completed, implementation went forward rapidly. In January, 1940, John F. Parsons arrived on the West Coast from Langley to direct the early construction phase at Sunnyvale. Edward R. Sharp, LMAL Administrative Officer, followed in March to set up the administration section and to negotiate contracts with the local public utility companies. Also in March, the NACA named the center the Ames Aeronautical Laboratory in honor of Joseph S. Ames, who served as Chairman of the NACA for many years. DeFrance came to direct activities at the laboratory in August, 1940, and a steady stream of Langley "alumni" transferred to the Ames Laboratory. Although the formal dedication of the


66. Interview with John F. Parsons; NACA Executive Committee Minutes, March 12, 1940.
laboratory was delayed until 1944 by the pressure of research activities, work began at the laboratory in late 1940.67

Truly the Ames Aeronautical Laboratory (now Ames Research Center) was a "child" of the Langley Laboratory. Virtually all planning for the station took place at Langley and all the early administrators and technicians at the Ames Laboratory received their practical training in LMAL activities.

Langley personnel planned still another laboratory built by the NACA in the early 1940's. The history and planning for the third NACA laboratory was quite similar to that of the Ames Laboratory. The Special Survey Committee on Aeronautical Research headed by Charles A. Lindbergh, which had advocated a West Coast laboratory, in October, 1939, submitted a report recommending "that an engine research laboratory be constructed at the earliest possible date." The Power Plants Division at LMAL which conducted all the NACA's engine research, faced deficiencies of electric power and space in common with all Langley activities.68


Following NACA approval of the Lindbergh Committee's recommendations, NACA Chairman Vannevar Bush named NACA Vice-Chairman George J. Mead to head a Special Committee on New Engine Research Facilities. In addition to representatives from the aircraft engine industry, the Mead Committee membership included Carlton Kemper, LMAL director of engine research. The committee formulated plans for equipment at the laboratory and submitted its findings to the NACA Executive Committee in February, 1940. After consultation with officials of the Bureau of the Budget, the NACA submitted an $8,400,000 request to Congress in the spring of 1940. This request for funds specified no particular site for the laboratory, an obvious remembrance of difficulties encountered in gaining an appropriation for the West Coast laboratory. With minimum difficulty, Congress authorized construction of a third NACA research station on June 26, 1940.

Following authorization, Bush appointed W. G. Whitney of LMAL to head a design committee for the planned engine laboratory. Rudolph F. Gagg of the Wright Aeronautical Corporation served as an industry consultant.

69. NACA Executive Committee Minutes, February 7, 1940.

70. The appropriation request said only that the NACA would select the site following Congressional approval. NACA 26th Annual Report, 1940, 2.
to the committee at Langley. Dr. Bush led the Special Committee on Site. Other members of the site selection committee were Lyman J. Briggs, National Bureau of Standards; Major General George H. Brett, Army Air Corps; and Captain Sidney M. Kraus, United States Navy. The Committee on Site visited 37 locations of the 72 offered for consideration. On November 25, 1940, Dr. Bush formally announced that Cleveland would be the site for the NACA engine research laboratory. The land selected consisted of 200 acres adjacent to the Cleveland Municipal Airport.

Almost immediately following selection of the site construction began. As had been the case with the Ames Laboratory, LMAL personnel provided the original

71. Gagg had much experience in designing facilities for the Wright Company. He also met with the NACA Committee on Power Plants for Aircraft and site selection committee. John D. Holmfeld, "The Site Selection for the NACA Engine Research Laboratory," Unpublished seminar paper, Case Institute of Technology, 1967, 18. (Copy of paper in NHA.)

72. All members of the site selection committee were also members of the NACA. NACA 26th Annual Report, 1940, 21.

73. New York Times, November 26, 1940, 27; "NACA's Third Lab Goes to Cleveland," Aviation, 40 (January, 1941), 76. A very complete account of the selection of Cleveland as the laboratory site is in Holmfeld, "The Site Selection for the NACA Engine Research Laboratory." This 1967 seminar paper written at the Case Institute of Technology is based for the most part on primary materials.
staff at the Aircraft Engine Research Laboratory (later the Lewis Flight Propulsion Laboratory). Virtually the entire power plant division at Langley transferred to the Cleveland laboratory. Edward R. Sharp directed the administration and Carlton Kemper, the research at the center. Although the original construction plans were not completed until 1944, the first investigation there began on May 8, 1942. Experience gained at LMAL aided in the establishment of both the Ames and Engine Research Laboratories. Problems which Langley faced in its early history were overcome, for the most part, in planning for the so-called "children of Langley."

With the addition of two new laboratories and an increased staff at Langley, involvement in war brought a new problem to the agency, namely, how to avoid having too many of the key personnel drafted into the armed services. Replacements for inducted employees could not meet the press of assigned research projects without training in Langley methodology—training which took more time than was available. John F. Victory, by direct contact with Selective Service officials, eventually reached an agreement allowing Langley to maintain its staff.

74. NACA Executive Committee Minutes, December 17, 1942; NACA 32nd Annual Report, 1946, 15, 39-40. The laboratory is today called the Lewis Research Center.
In the early war years, before an agreement was reached between the NACA and the Selective Service, Victory and W. Kemble Johnson of Langley handled most problems on an individual basis. By September, 1942, the armed forces had drafted 64 Langley employees and Victory convinced Selective Service Director Lewis B. Hershey to send a representative to LMAL "to study the NACA's personnel problem as affected by the Selective Service Act." During this period, Langley officials instituted procedures of their own. Paul E. Purser began a study of how long it would take to train a new college graduate to replace an inducted employee; he found that the replacement concept would not work due to lack of adequate time. Also, W. Kemble Johnson traveled to Richmond once a month to negotiate with the State Selective Service Director over the deferment of an employee considered "essential" by LMAL.

Again in 1943, officials of the Selective Service visited Langley with Victory to discuss draft

75. LMAL engineer Thomas L. K. Smull had been the seventh number pulled out of the fish bowl for the draft. Interview with Thomas L. K. Smull, December 12, 1966; NACA Executive Committee Minutes, September 10, 1942.

76. Interviews with Paul E. Purser and W. Kemble Johnson.
problems and again no agreement was reached. Victory spent many more hours conferring with General Hershey and the War Manpower Commission and, on January 27, 1944, NACA Chairman J. C. Hunsaker announced a NACA-Selective Service agreement. Essential NACA employees of draft age at LMAL entered an inactive status in the Army Reserve. They then performed "civilian duties under exclusive administrative management of the NACA." Langley employees also joined the Air Corps Enlisted Reserves (ACER). All employees holding reserve commissions resigned their commissions to become members of the ACER. The men inducted in this manner served absolutely no time on active duty. They spent 24 hours in Richmond taking a physical examination and completing other induction procedures. The oath of induction they recited included their assignment to the ACER on an inactive status. Laboratory employees received no military training and, following the end of the war,

77. One plan offered by Selective Service was to militarize all NACA physically able males, and make Lewis and Victory Air Corps Generals to direct the operation. The NACA completely rejected the proposal. Interview with John F. Victory, June 22, 1967. See also NACA Executive Committee Minutes, May 20, 1943, and U. S. House, Independent Offices Subcommittee, Hearings, 78th Cong., 1st Sess., 1943, 138; 78th Cong., 2d Sess., 1943, 118.

78. NACA Executive Committee Minutes, January 27, 1944.
were all granted honorable discharges. Through this method, Langley retained most of its essential employees throughout the wartime period.

Research conducted by the laboratory during the war consisted, to a great extent, of "clean-up" work. Due to the need for an immediate military buildup, little time existed to spend working on new airplane designs. Therefore Langley engineers carried on a minimal amount of fundamental investigations. Instead they worked on already-existing aircraft and improved the machines' efficiency as much as possible. To create a greater amount of coordination between LMAL and the services, the military established formal liaison channels with the laboratory. The Army Air Corps, as previously stated, appointed Major Carl F. Green to Langley Field in 1939, and placed him in charge of a liaison office there.

Major Green acted as the Air Corps representative in immediate dealings with the laboratory. His office funneled information collected at the laboratory to the

79. The system created some friction with Hamptonians who were inducted in the normal manner. Interviews with Caldwell C. Johnson, Paul E. Purser, and W. Kemble Johnson, all of whom were members of the ACER.

80. By 1940, George W. Lewis estimated that less than 50 percent of LMAL investigations were in the area of fundamental research. NACA Minutes, October 24, 1940; interview with Charles J. Donlan, January 15, 1968.
appropriate Air Corps division. LMAL engineer Donald Eastman and civilian Jean Rochet assisted Green when the volume of his work expanded following United States entrance into the war. 81

The Navy, preferring to have information routed through Commander Walter S. Diehl, did not establish an office at Langley. Diehl worked in the Washington office of the Naval Bureau of Aeronautics. Charles Helms of the NACA worked closely with Diehl and acted as liaison with research requests from the Navy. In addition Diehl visited LMAL often to investigate the progress of various projects. He and Helms were authorized to terminate a research project if they determined that no benefit would accrue from its continuance. 82 The Navy, as well as the Air Corps, sent service and industry representatives to Langley to aid laboratory engineers on certain projects. In this way these interested parties received data immediately upon completion of the research. The NACA estimated in 1942 that, at the request of one of the services, an average of 45 industry representatives

81. NACA Executive Committee Minutes, June 23, 1939; interviews with John F. Victory, June 22, 1967; Floyd L. Thompson, and Paul E. Purser.

visited LMAL every day, for advising and consultation work.  

According to previously arranged plans, the Army-Navy Aeronautical Board provided most of the coordination of NACA activities during the war. Following the institution of its mobilization plan in 1941, the Board used the NACA as its aeronautical consulting and research agency. Although the Aeronautical Board determined research priorities, the NACA decided which procedure would gain the desired results. The Langley staff also requested authorizations for particularly worthwhile investigations which the Board usually granted. Cooperation which existed between the military and the NACA as a result of the various procedures proved invaluable to the United States war effort.

One major area of cooperation involved improvement of existing military aircraft. This was accomplished by

83. Interview with Paul E. Purser; NACA 26th Annual Report, 1940, 1. LMAL also held secret technical conferences of Army, Navy and manufacturing representatives to discuss current problems. NACA Executive Committee Minutes, June 23, 1939.


a series of clean-up tests, which began prior to the war. Langley's original plan called for a program of drag clean-up. In essence, this consisted of placing a full size aircraft in the full-scale wind tunnel and determining which portions of the fuselage produced aerodynamic drag. To accomplish this, LMAL engineers covered the entire airplane with tape, making it aerodynamically smooth, and individually removed strips of the tape to determine the drag on each separate feature of the aircraft. Designers then reshaped these "defects" and, in many cases, significantly increased the maximum speed of a particular airplane.  

The first airplane tested by Langley for drag reduction was a Brewster XF2A-1, sent to the laboratory by the Navy on April 21, 1938. Langley engineers placed the aircraft in the full-scale tunnel and measured drag on its parts. These tests indicated that minor redesigning would increase the speed of the aircraft 31 miles per hour. Following the success achieved in the 1938 investigation, the military sent virtually every airplane

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86. Interview with Charles J. Donlan.

they contemplated using to Langley for clean-up tests. Examinations in the LMAL full-scale and propeller research tunnels resulted in maximum speed increases of between 25 and 50 miles per hour on all military aircraft.88

Shortly before American entrance into the war, one of Langley's major projects in the area of clean-up work was carried out on the Bell P-39 "Airacobra." Prior to construction of the airplane, Army Air Corps General Henry H. Arnold asked George Lewis if a 400-mile per hour plane could be built. Lewis gave Arnold information, gained from Langley research, for such an aircraft. Arnold sent the plans to Wright Field for transmittal to the Bell Aircraft Company. When originally built, however, the Airacobra's maximum speed was only 340 miles per hour. Dissatisfied, Arnold sent the plane to Langley to determine the reason for its performance below the predicted speed. Full-scale tunnel tests showed that modifications in the laboratory specifications caused a considerable increase in drag. Therefore, in conjunction with Air Corps and Bell engineers, the Langley staff streamlined the cooling ducts in the wing, reduced the size of the supercharger to create less of a protrusion,

sealed over the retracted wheels, and lowered the cabin six inches. These changes reduced the drag almost one-half and raised the speed close to the 400 miles per hour desired. This drag clean-up work continued through the war and gave American military aviators many advantages in wartime maneuvers. 

In addition to the modifications on the P-39, another of the laboratory's important wartime contributions was the low-drag wing used on the North American P-51 "Mustang." In 1940, the British purchased many of these airplanes from North American. Edward Schmood, North American design chief, adopted the principle of the low-drag wing for the P-51. Despite British acceptance

89. Additions of military equipment, however, reduced the maximum speed to 368 miles per hour. Interviews with Joseph N. Kotanchik and John F. Victory; "From the Wind Tunnels of Langley," Fortune, 23 (March, 1941), 146; James C. Fahey, U. S. Army Aircraft, 1908-1946 (New York: Ships and Aircraft, 1946), 33. Lewis also testified in 1939 that the Navy sent all its new airplane designs to LMAL for clean-up tests in the full-scale tunnel. U. S. House, Independent Offices Subcommittee, Hearings, 76th Cong., 1st Sess., 1939, 807.


91. See Chapter VII.

of the airplane's value, the U. S. Army Air Corps ordered very few until after this country entered the war. When the company modified the design for the U. S. Army Air Corps, North American designers established offices at LMAL and received "data from the wind-tunnel tests as it was obtained and (applied) it to their designs." The P-51 proved invaluable because it could escort, and provide protection for a bomber on its entire run, the only fighter airplane in the war which accomplished this feat. Langley's low-drag wing allowed the P-51 to conserve its limited fuel supply in order to travel the necessary distances. It is impossible to calculate the number of Allied bombers saved as a result of being protected by the P-51.

In addition to the drag clean-up tests in the full-scale wind tunnel, Langley engineers investigated

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93. For British evaluation of the low-drag wing, see E. P. Warner to G. W. Lewis, August 25, 1942; and Eastman N. Jacobs to Engineer-in-Charge, September 22, 1942, LaRC Files. Also see Fahey, U. S. Army Aircraft, 1908-1946, 34.


95. The Germans, because they had no low turbulence wind tunnels, had difficulty in determining what feature of the P-51 made it capable of such long distance flights. Interview with John F. Victory, June 22, 1967; John F. Victory, "The Early History of Aeronautical Research in the United States," Speech to the Air Research and Development Command, Baltimore, Maryland, April 24, 1952, 22.
many other military problems during the wartime period. Many research requests stemmed from reports received of activities in the war zone. Since the Navy and Army Air Corps had few instruments of their own, they often assigned service pilots to work directly with LMAL personnel in overcoming a particular problem. Secretary of the Navy Frank Knox said the "Army as well as the Navy...[depended]...on NACA to provide solutions for the technical problems incident to the requirement of a rapidly advancing technology."  

Investigators at the laboratory worked on many of the problems of stability and control of military aircraft. In late 1941, for instance, the Air Corps requested tests to determine the cause of and remedy for buffeting and diving accents on the P-38 airplane at high speeds. Pilots had difficulty applying "enough control to pull the aircraft out of a dive." The Army sent one of the airplanes to Langley where the 8-foot high-speed tunnel group under John Stack developed small flaps to place on the lower surface of the wing. These flaps gave the wing a positive lift coefficient and a downwash on the tail, both necessary to dive recovery.  

96. Interviews with Harold I. Johnson and Joseph N. Kotanchik.  

After this minor alteration, the Army ran immediate flight tests and, finding it successful, made the correction on its combat aircraft. Because of military necessity, LMAL conducted other investigations on tail loading on the P-47 for added safety and, by the end of the war, tested 120 different military airplanes in the laboratory's spin tunnels. The staff forwarded reports through liaison channels to the military establishing "tail design requirements...[indicating]...the minimum requirements for satisfactory recovery from a spin." These slight design changes were representative of many similar innovations produced at LMAL for increasing the flying qualities of military airplanes.

The Structures Division at Langley also played an important role in World War II. Forced ocean landings by bomber pilots often resulted in serious injury or death to the crew because of structural weaknesses of

98. Research Authorization No. 928, January 15, 1942, LaRC Files; interviews with Paul E. Purser, Harold I. Johnson, and Floyd L. Thompson. Tests at LMAL on the Army Air Corps B-24 by Jack Westfall showed that tail failures occurred only during a perfect "three-point" landing because of vibration created by all three wheels touching down at the same time. Interview with Richard V. Rhode, August 19, 1966.

the aircraft. At LMAL, Structures Division researchers
inverted the fuselages of a B-17, B-24, and B-25, and
applied loads to the bottom of the planes to simulate
the impact of water. After additional tests in the
NACA towing tank, Colonel Green, Army Air Corps
liaison officer, ditched a B-24 equipped with steel plates
fastened to the bottom into the James River. From a barge
in the river and a nearby bridge, laboratory people
photographed this landing to better understand the exact
nature of the impact. These tests resulted in the
development of a NACA "Hydroflap" to aid in ditching.
The flap was "capable of giving smooth ditching perfor-
ance under a wide variety of landing conditions," and
was undoubtedly responsible for saving the lives of many
bomber crews.

The war and its attendant problems placed a
considerable strain on all areas of activity at Langley.
Increases in the size of the staff, pressure to achieve
rapid results, and, of course, security restrictions all
complicated the comparatively relaxed atmosphere existing

100. Interview with Joseph N. Kotanchik.

101. See Chapter V.

102. Interview with Joseph N. Kotanchik; NACA
32nd Annual Report, 1946, 31, 35.
at the laboratory in the pre-war years. 103 A minor difficulty erupted with the industry over ownership of military airplane models which the industry had produced. Langley, after using the models for tests, wanted to retain them. Eventually negotiations between the NACA, military, and industry resolved the dispute. 104 Late in the war, LMAL's Engineer-in-Charge, Henry J. E. Reid became scientific chief of the ALSOS Mission sponsored by the War Department. The mission, to gather information on enemy scientific research and development, kept Reid away from the laboratory and John W. Crowley served as acting head of LMAL during Reid's absence. 105

Overcoming most of its problems, Langley performed a valuable function during the wartime period. Laboratory personnel tested 137 airplane types from 1941 to 1945. "These airplanes represent more than half of all the airplane types contracted for by the Army

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103. In 1942, Henry Reid warned Division Chiefs and Section Heads to be on "constant surveillance for probable fifth column activities such as agitation, propaganda, espionage, sabotage and actual physical attack." H. J. E. Reid, Memo to Division Chiefs and Section Heads, July 11, 1942, LaRC Files.

104. Russell G. Robinson to Edward Hartman, November 18, 1942, "Biography File," Box 32, Record Group 255, National Archives.

"and Navy," the NACA testified, "and include virtually all the types that saw actual service toward the end of the war." One aeronautical writer called the NACA the "research midwife at the birth of...better American planes."106 Following the war, the NACA, and its Langley Laboratory, continued to prove its value in the development of the world's first supersonic aircraft.

CHAPTER IX

RESEARCH IN HIGH-SPEED FLIGHT

Even during the war, LMAL researchers continued planning for aircraft capable of increased velocities. They aspired to achieve supersonic flight. To reach this goal, the NACA needed the assistance of both the military and the industry. Naturally, these activities and plans were given less prominence during the war because more immediate military problems required investigation. Military priorities, however, did not prevent engineers like John Stack, who had been interested in the problems of high-speed flight since the time he began work at LMAL in 1928, from continuing their work. George W. Lewis, NACA Director of Aeronautical Research, also strongly supported the desire to reach greater speeds. He encouraged the Langley staff to continue its scientific investigation of the problems of supersonic flight.¹

Researchers had to perform investigations in three distinct speed ranges: subsonic, wherein the flow over all parts of an aircraft are at speeds below the speed of sound; supersonic, wherein all flows are above the sonic level; and, most importantly, transonic,

wherein local areas verge on the speed of sound although an aircraft is flying at a subsonic velocity. During the time when research was conducted leading to a supersonic aircraft, no wind tunnels existed which could produce transonic flow. Wind tunnels with air flows at supersonic speeds tended to choke when operated in the transonic range. Supersonic testing was possible as early as 1928 with the construction of the 11-inch jet tunnel at LMAL. But in the limbo just above and just below Mach 1.00 (speed of sound), other methods were needed.

Observation of the transonic speeds was essential in overcoming a phenomena known as a "compressibility burble." Basically this condition is the bunching up of air on the upper portion of a wing as an airplane approaches the speed of sound. Instead of smoothly flowing over a wing, the air piles up and creates an impediment through which flight is very difficult. The unpredictable air flow causes the wing to lose its lifting power and makes control of the aircraft extremely difficult. This problem, occurring generally between 600 and 900 miles per hour, had to be solved before supersonic flight was attainable.  

2. See Chapter V.

In the mid-1930's John Stack and his research team investigated compressibility effects on airfoils in Langley's new 24-inch high-speed wind tunnel. These tests, using flow photographs produced by the Schlieren method, showed great drag increases stemming from "a compression shock that occurs on the airfoil as its speed approaches the speed of sound." In the background studies leading to supersonic flight, it appeared to George Lewis and other NACA officials that compressibility problems would be most crucial in regard to propellers but, with advances in jet and rocket propulsion, no need existed for further research in this area. Additional experimentation in the 24-inch high-speed tunnel, and theoretical studies by Antonio Ferri still did not provide enough information on phenomena in the transonic region.


7. Ferri, formerly a major in the Italian Air Corps, came to the United States near the end of the war to work at LMAL. NACA Minutes, October 19, 1944; Stack, Lindsey, and Littell, Technical Report No. 646, 73-96.
engineers therefore devised other methods for acquisition of the desired data.

During one of Lewis' many visits to LMAL to discuss the problem of gathering data on transonic speeds, John W. Crowley suggested a "falling body" concept. This involved mounting a wing model on a bomb-shaped missile and dropping this body at great altitudes from an airplane. Electronic telemetering could then measure the flow of air around the wing model as the body dropped to the ground. Advances during the early 1940's in radar and other devices made this concept possible. Edmund C. Buckley, later in charge of the LMAL Instrument Research Division, led the team which developed the telemetering equipment to record the forces on the falling projectile.

A borrowed B-29 carried the fully instrumented missile to an altitude of about 30,000 feet and, at a speed of approximately 300 miles per hour, released it. Instruments inside the body measured several of the forces of pressure and drag on the wing model, while ground observers received the relayed radio signals through telemetering devices. Since the body covered a

8. Interview with John Stack.
full range of speeds in its descent, some information could be gathered on its passage through the transonic range. Prior to the end of the war, however, limited refinements in the sophistication of electronic equipment restricted the gathering of a great deal of information in this manner.

In 1944, Robert R. Gilruth of the LMAL Flight Research Division devised a method for gaining a greater amount of information on the flow around an airfoil during transonic flight. Gilruth knew that a P-51, during a dive, reached a speed of approximately Mach .75, but the flow of air over a portion of the wing went to Mach 1.2. This flow went "quite smoothly through the


11. Interview with John Stack. Research on rockets and greater speeds became more sophisticated with the establishment of the Pilotless Aircraft Research Station on Wallops Island, Virginia, in June, 1945. The center was yet another "child" of LMAL. NACA Executive Committee Minutes, September 13, 1945. Joseph A. Shortal, former director of this station, is presently preparing a history of the NACA research on Wallops Island.

speed of sound." Although by his own admission he was not an expert in air flow research, Gilruth felt this airstream could be utilized as a "flying wind tunnel."

With Harold I. Johnson building strain gauge models, Gilruth devised a small balance to measure drag and lift of the airfoil being studied. 14

To conduct tests using this wing-flow method, as it was called, engineers mounted an airfoil model perpendicular to the wing in its supersonic flow region, which exists at high subsonic speeds. 15 The pilot of the carrier airplane, after reaching the desired altitude, dove the aircraft as rapidly as could be safely accomplished. As the speed of the airplane in its dive increased, air flow against the wing-mounted model passed smoothly from subsonic into supersonic speeds and the tiny instruments recorded the model's reaction to the transonic velocities. 16


14. Ibid.


Some LMAL engineers, who were interested primarily in wind tunnel investigations, felt that the testing method developed by Gilruth was somewhat unscientific because of his relative disregard for Reynolds number. Gilruth agreed with the criticism but, until a transonic wind tunnel was available, he felt the wing-flow method would provide a substantial amount of data. According to Gilruth, the results of the wing-flow tests, along with tests on the P-47, led to the conclusion that supersonic flight required a thin wing. An entire series of wings of various thicknesses underwent wing-flow examination, culminating in the NACA 6 Series of airfoils eventually used on the X-1.

Even with the data acquired in these various manners, it was obvious that flight testing was the next logical step. Officials of the NACA realized, however, that the agency itself could not unilaterally accomplish

17. No transonic wind tunnel existed until late 1947.

18. When eventually flown, the X-1 had an 8 percent thick (thickness divided by wing chord) wing, considerably thinner than those commonly used. Gilruth credits the decision to use a thin wing to Floyd L. Thompson. Interview with Robert R. Gilruth.

19. Interviews with Harold I. Johnson and John Stack. The original designation of the first supersonic aircraft was the XS-1 (experimental supersonic). For convenience, the later, commonly accepted designation X-1 is used throughout this chapter.
this program. The charter of the NACA did not allow
construction of a complete airplane. Furthermore, the
project, as John Stack and George Lewis pointed out,
would be extremely expensive; and the NACA budget,
strained by military research, could not finance such a
program. In addition, the project proposed by Stack in
1943 was a considerable departure from previous research
procedures. He suggested that an aircraft be constructed
solely for research purposes. The aircraft would be fully
instrumented to gather as much data as possible.

LMAL engineer Milton Davidson formed a team in
the summer of 1942 to work on design proposals for the
required research aircraft. Naturally the Davidson team
modified its design proposals as increased information
became available. Most of this data was derived from
freely falling body and wing-flow examinations. George
Lewis, made somewhat hesitant by wartime pressures, fully
supported steps leading toward the achievement of
supersonic flight. Finally, in 1943, LMAL officials
commenced definite steps toward gaining the cooperation
necessary to produce a research aircraft.

20. Interview with John Stack.
21. Interview with Floyd L. Thompson, January 16,
1968.
22. Interview with John Stack.
Stack sent a memorandum to both the Army Air Force engineers at Wright Field, Ohio, and the Naval Bureau of Aeronautics in 1943, proposing cooperation between the services and the NACA for construction of a research aircraft. At the time he submitted this memorandum, Stack was not certain it would result in a supersonic aircraft, but was interested in gathering increased data on transonic flight. Thus the new concept of an aircraft to be built specifically for research purposes was born.

Although both the Army and the Navy desired explorations in the field of high-speed flight, Major Ezra Kotcher, chief of Army Air Force research at Wright Field, was, at the time, beset with problems of coping with buzz bombs and could not make an immediate response to the research aircraft suggestion. In March, 1944, however, at a meeting of Air Force, Navy and LMAL personnel, the NACA proposed that a transonic research

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24. Interviews with Floyd L. Thompson and John Stack.
aircraft be developed for use as a "flying laboratory." The airplane was in no sense to be a tactical aircraft nor ever to be a commercial product, but rather designed to acquire fundamental data attainable in no other manner. John Stack led the LMAL drive for a piloted aircraft able to obtain velocities high enough to acquire reliable transonic data. While this program eventually led to the development of a supersonic aircraft, Stack's purpose was primarily to gather data in the somewhat mysterious transonic region.

Cooperative efforts among the NACA, the Army Air Force and the Navy continued throughout 1944. To give wider scope to the investigation of high speeds, the participants decided that each service should develop its own aircraft for research purposes. The NACA assisted the Navy and the Air Force in designing and testing their aircraft. LMAL personnel, of course, had primary responsibility for providing results applicable to the design of an experimental aircraft. The laboratory also


27. Interview with John Stack.
developed instrumentation for the aircraft to measure all forces encountered by the airplane during flight tests.28

With preliminary plans completed, another problem arose, namely, which companies would actually design and build the aircraft? Finding a company to build the aircraft was not a simple matter. Because the aircraft built would be for research purposes only, the company could expect no profits to ensue from later production of these models. The Navy convinced the Douglas Aircraft Company of the worth of the project and it built a research aircraft, later called the D-558.29 This airplane, powered by a turbo-jet engine, took off from the ground rather than being launched in flight, and had a more slender and longer fuselage than the X-1. First flown in early 1947, the D-558 broke the official world speed record in August of that year. LMAL engineers held many meetings with Douglas Company personnel during the design and construction of this aircraft. Laboratory staff members also attended all flight tests.30


29. Edward Heineman of Douglas Aircraft had worked closely with Navy design engineers on earlier projects.

At a December, 1944, meeting at LMAL, John Stack and Ezra Kotcher broached the idea of building a research aircraft to the Bell Aircraft Corporation. Robert Woods, a Bell officer, had worked with Stack at LMAL, and felt the research aircraft idea was very valuable to the advancement of American aviation.  

Robert Stanley, Bell Chief Engineer, suggested dropping the aircraft from a "mother" airplane. At first, LMAL engineers doubted the feasibility of this idea but were convinced by Bell designers that it would be accomplished.  

The Army Air Force signed a contract with the Bell Company in May, 1945, to build the X-1. Company President Lawrence D. Bell appointed Stanley Smith the project manager. Smith, as well as his successor Richard Frost, maintained close contact with both Air Force and LMAL engineers. In this manner, Bell could incorporate the latest research results acquired at Langley. LMAL investigators continued supersonic airfoil examinations, using freon gas as a test medium since the speed of sound in the freon gas is only half of that in air.

31. Interview with John Stack.
32. Interview with Floyd L. Thompson.
33. Woolams, Aviation, 45 (September, 1946), 38.
34. Structural heating problems also were studied. NACA 32nd Annual Report, 1946, 3; NACA 33rd Annual Report, 1947, 33; Interview with Joseph N. Kotanchik, June 27, 1967.
Despite the swept-wing research carried out by Robert T. Jones of LMAL, Bell designers decided that a thin, straight wing would suffice. As the aircraft was built to fly at speeds never before achieved, engineers included very few radical design innovations. The power plant for the X-1 was a four-barrel rocket engine developed by Reaction Motors, Incorporated of New Jersey. Because a rocket engine consumed its fuel very rapidly, and weight restrictions prevented the carrying of great amounts of fuel, the Bell engineers designed the X-1 to be carried to an altitude of 30,000 feet by a specially modified B-29 and then dropped for flight. When completed, the X-1 had a twenty-eight-foot wing span, was thirty-one feet long and eleven feet high, weighed 4,892 pounds empty and carried 8,000 pounds of fuel for its rocket mechanism.

35. An NACA Series 6 wing, with a high critical Mach number was used on the X-1. Interview with John Stack. See also U. S. House, Committee on Appropriations, Subcommittee on Independent Offices, Hearings, 80th Cong., 1st Sess., 1947, 120; and "Supersonics," Life, 22 (January 6, 1947), 53.


37. Woolams, Aviation, 45 (September, 1946), 38.

Under terms of its contract with the Air Force, the Bell Company agreed to test the X-1 to a speed of Mach 0.8 prior to Air Force acceptance of the aircraft. For this reason, Bell designed the original cockpit to the physique of its chief test pilot, Jack Woolams. All other available space was allotted to instrumentation. 39 Because of a delay in the completion of the rocket motor, Woolams, in early 1946, flew a series of glide tests of the X-1 at Pinecastle Air Force Base, Florida. These gliding tests proved the aircraft to be aerodynamically sound, and plans for powered flights followed. 40

Woolams also was to make the company flight tests with power. However, he died making another test before installation of the X-1's rocket motor. To replace Woolams, the Bell Company selected Chalmers H. "Slick" Goodlin, whose physical size was similar to that of his predecessor. On December 9, 1946, Goodlin flew the first test flight of the X-1 with rocket power. He subsequently flew the company tests to the Mach 0.8 speed

39. Woolams, Aviation, 45 (September, 1946), 38. Woolams also hoped to be the pilot of the first supersonic flight.

required by contract prior to Air Force acceptance of the aircraft. 41

While these tests were in progress, the Air Force and the NACA chose the site to conduct flight tests to be made upon completion of the company performance requirements. They selected a relatively small Army Air Force test facility at Muroc, California. 42 Many factors, in addition to the Air Force contingent already there, made Muroc an appropriate site for the X-1 tests. An enormous stretch of desert provided adequate landing space. The facility's remoteness effectively removed the danger of a test failure causing damage to a populated area. A lake near the testing site offered a convenient spot to come down in case of difficulty with the aircraft's landing gear. Air Force and NACA project managers also took into account the favorable flying conditions at Muroc. Approximately ninety-five percent of the time is suitable for flight tests. 43


42. This site later became the Edwards Air Force Base.

43. Interview with John Stack.
In September, 1946, Hartley A. Soulé, LMAL project manager for the research aircraft program, and a team of engineers and observers moved to the California station. This group, called the NACA Muroc Flight Test Unit, was under the immediate direction of Walter Williams. The members supervised the complete instrumentation of the X-1, and the gathering of all possible information from the test flights. Over 500 pounds of instruments were placed in the X-1, leaving only the cockpit room for the pilot. This crowding was necessary to insure that the X-1 served its intended function: an aircraft conceived and built to acquire data on transonic and supersonic flight.

Bell delivered the X-1 to the Air Force in the summer of 1947. Colonel Albert Boyd of the Air Force

44. Interview with Hartley A. Soulé.

45. Today this installation is the NASA Flight Research Center. Its establishment is yet another example of LMAL-trained personnel founding a research facility.


selected a team of test pilots to begin a series of flights with the aircraft. The NACA and the Air Force agreed to coordinate their plans so that the aircraft could be flown, as soon as possible, to the limit of its capabilities. Implied in this agreement was scheduling by the NACA of a series of research flights to gain a sufficient amount of scientific flight data. 48

With these not entirely opposing ideas in mind, Air Force pilots in July, 1947, began a series of flights of the X-1 at the Muroc station. Plans called for each successive flight to be slightly closer to Mach 1.0. Pilots, soon after initiating the program of flights, flew the X-1 to speeds of Mach 0.90, 0.92, and 0.96. 49 As the sonic barrier was approached, pilots reported that the aircraft performed with very little difficulty.

On October 14, 1947, Captain Charles E. Yeager, the test pilot, intended to fly the X-1 to approximately Mach 0.97. 50 Fastened under a B-29 Superfortress, the X-1 was carried to an altitude of approximately 30,000 feet. After pressurizing the cabin of the X-1, Captain Yeager lowered himself from the B-29 by cable into the

50. Interview with John Stack.
cockpit. With his signal, the aircraft was cut loose at a speed of 240 miles per hour. Yeager activated the X-1's rockets and soon reached the desired speed of Mach 0.97. He was in a slight climb and all systems operated perfectly. In an on-the-spot decision, Yeager decided to extend the flight slightly and, to the amazement and approval of the ground observers, flew the X-1 to approximately Mach 1.1. After a flight of just over two minutes, Yeager's fuel was consumed, as planned, and he decelerated rapidly back through Mach 1.0. He glided the X-1 to earth at 400 miles per hour, landed at 160 miles per hour, and coasted across the desert for almost two miles before coming to a halt. 51 Less than forty-four years after the first flight of the Wright brothers, man had achieved level flight at supersonic speeds.

Obviously extensive supersonic flight was not yet practical. However, NACA Chairman Jerome C. Hunsaker praised these early flights for the "scientific information that is being obtained about the problems of flight at high speeds." 52 Subsequent X-1 tests provided data in


many areas under investigation including "stability and control, methods of pilot escape, aerodynamic heating, scale effect, and similar general problems."\textsuperscript{53}

The value of the achievement of supersonic flight was widely accepted. As a result, on December 17, 1948, President Harry S. Truman presented the Collier Trophy, emblematic of outstanding aeronautical contributions, to John Stack of LMAL, Lawrence D. Bell, president of the Bell Aircraft Corporation, and Captain Yeager, pilot of the world's first supersonic flight.\textsuperscript{54}

Just as the original flights of the Wright brothers in 1903 had been unpublicized for a time,\textsuperscript{55} news of the world's first supersonic flight temporarily remained a secret. The Air Force classified information concerning the supersonic achievement because of cold war tensions. This was done despite the fact that the military had previously released pictures of the X-1, and acknowledged the purpose of the aircraft. Only the flight at supersonic velocity was kept secret.

\textsuperscript{53} Dryden, "The Aeronautical Research Scene---Goals, Methods and Accomplishments," 35.

\textsuperscript{54} \textit{New York Times}, December 18, 1948, 1.

\textsuperscript{55} See Chapter I.
Revelation of the X-1 flights was made in December, 1947, in an *Aviation Week* article. The release of the information resulted in a mild controversy, although *Aviation Week* claimed that the Air Force itself was preparing to announce the achievement. Finally, after an investigation by the Justice Department, and announcement by Attorney General Thomas Clark that *Aviation Week* had not violated any federal law by its December, 1947 story, Air Force Secretary W. Stuart Symington, on June 10, 1948, confirmed the veracity of the magazine article.

On this successful note, the third decade of research at the Langley Laboratory came to a close. Supersonic flight, a truly cooperative venture, opened new vistas to aeronautical engineers. The event was a watershed in aeronautical history and began a new era which is today on the verge of "hypersonic" flight.


CHAPTER X

THE LANGLEY EXPERIENCE

Few governmental institutions have had as great an impact on their specific areas of activity as the Langley Laboratory has had on American aeronautical development. From its establishment in 1917 to the beginning of World War II, LMAL engineers carried out the only major effort in fundamental aerodynamic research in the country. The opening of the Ames Laboratory shifted a portion of the basic investigations to the West Coast but, Langley personnel staffed the new center, and all research conducted was still under the banner of the parent organization—the National Advisory Committee for Aeronautics.

As aviation concepts evolved during the first half of the twentieth century, interest in aeronautical developments became more widespread. Universities introduced to the curriculum offerings in aeronautical engineering. Comparatively early, the military services realized the value of airplanes for national defense. Also, forward-looking military leaders recognized that the United States would have to keep pace with the accomplishments of other nations in aeronautics in order to protect its interests. Of course "plotting" for
another war was not involved, but a primary function of military strategists is the preparation for any eventuality.

With the realization that the United States aerial strength was almost nonexistent when the first war opened in Europe, Congress had authorized formation of the NACA. The policy-making structure under which the Committee operated was unique among governmental agencies. With an appointed, unpaid committee directing the organization, opportunities for financial manipulation for personal gain were negligible. In addition, because only a few agency investigations required contracts, private firms were not tempted to exert undue influence. Examinations conducted at the field laboratories were relatively open, and published results could be used by any company desirous of adapting the data to its aircraft. A company might desire to have an investigation conducted in regard to one of its specific airplane designs. If necessary, the firm would pay for the carrying out of the tests.¹ Likewise the military services could support financially an investigation when required.

¹ This "hiring" of the laboratory staff and monetary interchange was a rare occurrence. Interviews with Floyd L. Thompson, January 16, 1968; and Ralph E. Ulmer, December 20, 1966.
Establishment of the Langley Laboratory by the NACA proved a boon to American aeronautical development. Especially in the pre-World War II years, the industry was unable to finance fundamental research in aerodynamics. Constructing the necessary wind tunnels, and hiring a competent staff of researchers was far too expensive for a company's resources. Only the federal government had sufficient funds to finance the search for fundamental data required to improve American aviation capabilities.

In a general sense, all research projects at LMAL concerned one of the two major areas of flight: improved efficiency of an aircraft or increased safety during a flight. Of course these two concepts are not mutually exclusive. Developments in flaps or tails, for instance, permitted construction of more efficiently operating airplanes which might also be able to pull out of a spin more easily. Langley research, besides serving a military need, also indirectly benefited the general public. Fundamental investigations conducted and innovative results achieved improved the operation and safety of commercial aircraft as well as those of the military. Increased efficiency allowed commercial airlines to improve scheduling and reduce the expense of air travel. Except for the results of classified tests, the NACA published its findings for use by all aircraft
designers and, although the agency often received no
direct credit, LMAL ideas were incorporated in most
contemporary airplanes. ²

Langley played an invaluable role in the technical
evolution of American aeronautics. Laboratory engineers
investigated all aspects of flight and published their
results. Wing shape, loading, stability and control,
icing problems, power plant innovations, structures,
landing gear, propellers, cowlings, and aircraft
instrumentation all underwent study by Langley engineers.
And, generally, improvements in each area resulted from
this experimentation. In 1947, the President's Scientific
Research Board attested to the worth of the efforts of
the NACA and its laboratories. "There is not an airplane
flying today which does not bear the work of NACA
research. Cowlings for air-cooled engines, airfoil
sections, control surface shapes and sizes, propeller
designs," the report continued, "...have been predicated
largely on the research information that has come from
the NACA laboratories."³

² This held true in almost any period in
LMAL's history.

³ U. S. President's Scientific Research Board,
Science and Public Policy, A Report to the President by
John R. Steelman, Chairman, September 27, 1947, II, 255.
Another facet of the story of the Langley Laboratory which must not be overlooked is its development of many new aeronautical research tools. From its very humble beginning with a wind tunnel copied from previously constructed European models, Langley engineers devised and built a variety of wind tunnels capable of measuring all aspects of flight. The laboratory staff was willing, if funds could be acquired, to attempt to materialize new concepts in wind tunnel technology. If funds were difficult to acquire, as during the depression years, the personnel reduced construction costs wherever possible by borrowing materials, applying for support as "make-work" projects, and using unskilled laborers.

No single private enterprise in the United States could afford the capital investment required to duplicate the many facilities at Langley. By "pooling the national resources" and operating in the public interest, the NACA developed a fairly complete central location for investigation of all the phenomena of flight. In this way, also, competition for fundamental aerodynamic data was reduced considerably. Centralization and coordination of research activities by the agency and its laboratory also reduced wasteful duplication of effort.

4. Interviews with Thomas L. K. Smull, December 12, 1966; and Floyd L. Thompson.
to a bare minimum. When necessity dictated that additional fundamental research centers be established, LMAL personnel proved quite capable of planning and supervising the operation of the new laboratories.

The most important key to the success of the Langley Laboratory can be expressed in a single word, cooperation. This concept pervades the entire history of laboratory activities; it is implied in every area in which the laboratory operated both internally and externally. The amenable relationships throughout this period are almost unprecedented in governmental activities. Without this cooperative spirit the achievements might have been immeasurably reduced.

An important example of this cooperative spirit, of course, was the attitude among the Langley Laboratory staff. Minor competition between personnel of the various research divisions could not detract from the high regard the employees had for each other. They functioned as a team in the fullest meaning of the word. Although an engineer might not be completely involved in an investigation one of his co-workers was conducting, ample opportunities existed for the discussion of research problems and exchange of ideas. Moreover, in the pre-World War II years, with a small staff located in a fairly restricted geographical area, separate divisions
of the laboratory existed on organizational charts but not in actual practice. Division Chiefs and Section Heads added to the cohesiveness of the staff, for they also were researchers and were not exclusively administrators. These administrators had formerly been co-workers with the men in their respective sections. All Langley promotions were made from within.

The staff not only worked together, ate lunch together, but also, in the case of many of the unmarried employees, shared living accommodations. As mentioned, the social life of most of the employees centered around their working associates at the laboratory. An intense feeling of community existed among the Langley personnel.  

LMAL Engineer-in-Charge Henry J. E. Reid recognized the value of the constant associations among laboratory employees and promoted it wherever possible. To further extend dialogue among the staff and administrative branch of the laboratory, Reid maintained an "open door" policy in his office. Any employee could

5. One example of the willingness of Langley engineers to attempt the "unlikely" was the activity of Eastman N. Jacobs. In 1928, Jacobs, later to receive the Collier Trophy for his work on airfoils, constructed his own monoplane (in his leisure time), and taught himself to fly! Newport News Daily Press, December 19, 1937.

6. Told to the author in a great number of interviews.
come to Reid to discuss laboratory problems without upsetting the center's formal chain of command. He also made sure that adequate open-ended discussions occurred throughout the course of all research projects so that any technical disagreements could be amicably resolved.

No less important to the success of the Langley operation were the cordial and mutually respectful relations between the laboratory staff and the Washington office of the NACA. Until the opening of the Ames and Lewis Laboratories, LMAL constituted the only operational arm of the agency and was therefore the exclusive institution through which the NACA functioned. George W. Lewis and John F. Victory were both essential to this beneficial relationship. Lewis took an enormous interest in all research activities of the laboratory and showed a willingness to listen to new concepts and research ideas of laboratory engineers. He also personally met with as many employees as possible during his frequent

---

7. One excellent example of this was Lewis' reaction to tests successfully conducted by John Stack in supersonic aerodynamics. After the Director of Aeronautical Research told Stack that the tests could not be conducted because of wartime pressures and Stack proceeded anyway, some worry existed over what reaction Lewis would have. When Lewis viewed the results of Stack's tests, however, he said that if he ever gave another such foolish order, to disregard it again! Interviews with John Stack, January 31, 1968; and Walter S. Diehl, September 12, 1967.
visits to the laboratory. Lewis combined the roles of government official, agency administrator, and technical authority and won much loyalty from the personnel at Langley. He, as much as any single man, must be given credit for the overall success of the NACA.

John F. Victory, the counterpart of Lewis in directing administrative affairs of the agency, devoted his entire career to the NACA. As the agency's first employee in 1915, Victory took on the task of keeping "red tape" to a minimum and ensuring fulfillment of the NACA's primary function: conducting scientific research into the phenomena of flight. His interest and efforts in planning LMAL's annual inspections proved of incalculable value in gaining favorable publicity for the laboratory. Few details which would improve the smooth operation of the NACA escaped the watchful eye of Victory.

Victory's most important activity in promoting the welfare of the agency and its laboratory, was his role as liaison between the NACA and Congress. At the opening of each new Congress, Victory visited the offices of all new Representatives and Senators, and informed them that he would be happy to forward them any information desired concerning aeronautical research. Also
whenever a Congressman wished to visit LMAL, Victory made the arrangements and usually accompanied the guest.

Both Lewis and Victory, along with Joseph S. Ames, carried the brunt of testimony for the NACA before the House Independent Offices Subcommittee of the Committee on Appropriations. This was, of course, all-important to laboratory activities as expanded research was impossible without adequate funds. These three men built up such a degree of credibility in their testimony that, for many years, NACA officials testified only before the appropriations subcommittee and were not required to appear before an authorization committee.8 LMAL officials assisted in welcoming important Congressional officials to the laboratory.9 In these ways, the theme of cooperation was extended not only within the agency, but with the Congress as well.

Absolutely vital to Langley advancement was continued happy relations between the laboratory and the military services. The presence of military representatives on the full, executive, and various technical

8. Interview with Ralph E. Ulmer.

9. "Camp Langley" was established as a retreat where Congressmen, along with LMAL employees, could relax and fish at their leisure. Interviews with Pearl I. Young, January 9, 1967; and John F. Victory, June 22, 1967.
subcommittees of the NACA provided a forum for the constant interchange of ideas and the solutions of any problems which arose. Maintenance of cordial relations at Langley Field, following the early period of strain, benefited both the military and the NACA. When the laboratory needed an aircraft to complete flight tests on a project, both the Army Air Service and the Naval Bureau of Aeronautics cooperated by providing these airplanes to the Committee at no cost.

Important figures in military aeronautics often visited the laboratory and, in many instances, worked with LMAL engineers to overcome a particular military problem. Certainly the most beneficial of these joint investigations were the Langley "clean-up" tests during the Second World War. Although few formal combined projects existed prior to the X-1 program, informal interchanges of information occurred following LMAL's establishment. One could list numerous examples of friction between the armed services and the NACA, but almost all of these were of a minor nature and did not interrupt the amicable spirit characteristic of the relationship. Both the military and the NACA worked
toward the same basic goal, improvement of the aeronautical capabilities of the United States. 10

Representatives of the aviation industry also appreciated the value of Langley research. Realizing that they could not financially sponsor fundamental investigations to the extent possible at LMAL, industrial lobbyists aided the laboratory by speaking in favor of increased budgets for the NACA. The laboratory cultivated this industry support through both its worthwhile investigations and its brilliantly conceived and conducted annual inspections. Grover Loening and the late William Littlewood, both very important figures in the aviation industry, agree that the annual inspections at LMAL were as important in promoting good will as anything the laboratory accomplished. 11

Although there was some "competition for credit" 12 between the industry and LMAL, tests of industry models and prototypes, along with the publication of research results by the laboratory, gained the gratitude of the

10. The NACA also kept the military informed of European aerodynamic developments through the committee's Paris office established in 1919 under John J. Ide. C. D. Walcott to Secretary of War, May 20, 1919, NASA Historical Archives.


12. Interview with Floyd L. Thompson.
of the industry. As in the case of military technicians, the industry sent engineers and designers to consult with Langley personnel about innovations in their production aircraft. NACA policy ensured that "industry specialists were welcome to discuss technical matters and work in progress with NACA people at the laboratories." Many advantages accrued from the cordial relations between the Langley Laboratory and the United States aviation industry.

An area seldom noted but not without importance to the welfare of the laboratory was its cooperation with the academic community. Assuredly the majority of benefits went to the universities, but LMAL required adequately trained college graduates to replenish and increase its staff. In the 1920's, before numerous textbooks were available, university professors of aeronautical engineering often used NACA technical reports as teaching materials. Also, because LMAL constituted the nation's only center for fundamental research in aerodynamics, professors often recommended employment at Langley to their outstanding graduates.  


The NACA and LMAL, whenever possible, allowed tests to be run for the universities and often donated models and small equipment for classroom use. Aeronautical engineering students also visited the laboratory and viewed actual operation of LMAL's equipment. Later, agreements with Virginia universities permitted LMAL junior aeronautical engineers to take some graduate training while holding a full-time laboratory position. Officials of the Langley Laboratory fully realized the value of close cooperation with aerodynamic studies at American universities. 

All the activities at the Langley Laboratory in the years 1917-1947, and indeed to the present day, must be viewed within the context of this cooperative spirit in all respects. It is difficult to conceive of the efficient operation and truly innovative achievements accounted herein without understanding the value of the peaceful surroundings in which they occurred. No single concept can be pointed to as more influential in the successful evolution of aeronautical research in the United States than the aura of cooperation.

15. See, for instance, NACA Executive Committee Minutes, March 19, 1926; and NACA 16th Annual Report, 1930. 18. Following World War II, competition for employees became greater, and formal recruiting trips to the universities were instituted. Interview with T. Melvin Butler, January 12, 1967.
Since prior to World War II, no other laboratory devoted to fundamental research in aerodynamics existed in this country, the value of the Langley Laboratory is obvious. Virtually every airplane flying in the United States shows some results of LMAL studies. Surely the advancement of aviation in this country would have been severely retarded had not Langley existed. The laboratory's experience remains one of the outstanding tributes to governmental sponsorship of scientific research. In its method of operation, and the illustrious results achieved, the Langley Laboratory fulfilled the true potential of federal activities in the progress of mankind. Though the story of Langley herein related ends in 1947, the laboratory continues to the present to be a major contributor to fundamental research in aerodynamics.
An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences: Provided, that the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: Provided further, That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and provided further, That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.

That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and necessary expenses of members of the committee in going to, returning from, and while attending, meetings of the committee: Provided, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.
APPENDIX B

CHAIRMEN OF THE NACA

George P. Scriven  
Brigadier General, U. S. A.  
Chief Signal Officer  
1915-16

William F. Durand  
Prof. and Head of Department of Mechanical Engineering  
Stanford University, California  
1916-18

John R. Freeman  
Consulting Engineer  
Providence, R. I.  
1918-19

Charles D. Walcott  
Secretary  
Smithsonian Institution  
1919-27

Joseph S. Ames  
Professor of Physics  
President, Johns Hopkins University  
1927-39

Vannevar Bush  
President  
Carnegie Institution  
Washington, D. C.  
1939-41

Jerome C. Hunsaker  
Head of Departments of Aeronautical and Mechanical Engineering  
Massachusetts Institute of Technology  
1941-56

James H. Doolittle  
Vice President, Shell Oil Co.  
New York  
1956-58
**APPENDIX C**

**MEMBERS OF THE NACA**

<table>
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<tr>
<th>Name</th>
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<tr>
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<td>Joseph S. Ames</td>
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<td>Allen V. Astin</td>
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<td>Thurman H. Bane</td>
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<tr>
<td>Preston R. Bassett</td>
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<td>George H. Brett</td>
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<td>Lyman J. Briggs</td>
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<td>Detlev W. Bronk</td>
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Fred D. Fagg, Jr. 1937-1938
James E. Fechet 1928-1931
Aubrey W. Fitch 1944-1945
Paul D. Foote 1957-1958
Benjamin D. Foulois 1929-1930
1932-1936
John R. Freeman 1918-1919
Clifford C. Furnas 1956-1957
Mathias B. Gardner 1952-1953
William E. Gillmore 1926-1929
Willis R. Gregg 1934-1938
Harry F. Guggenheim 1929-1938
Lloyd Harrison 1953-1955
John F. Hayford 1915-1923
Ronald M. Hazen 1946-1955
Clinton M. Hester 1938-1940
Robert H. Hinckley 1939-1942
Wellington T. Hines 1957-1958
Jerome C. Hunsaker 1922-1923
1938-1958
William L. Kenly 1918-1919
Walter G. Kilner 1939-1940
Ernest J. King 1933-1936
Sydney M. Kraus 1936-1943
Emory S. Land 1923-1929
Charles A. Lindbergh 1931-1939
William Littlewood 1944-1953
Theodore C. Lonnquest 1947-1952
John S. McCain 1942-1944
Charles J. McCarthy 1957-1958
Lawrence W. McIntosh 1923-1924
William P. MacCracken, Jr. 1929-1938
Charles F. Marvin 1915-1934
George J. Mead 1939-1944
Charles T. Menoher 1919-1921
Marc A. Mitscher 1945-1946
William A. Moffett 1921-1933
Denis Mulligan 1938
Robert B. Murray, Jr. 1953-1954
Edward J. Noble 1938-1939
Byron R. Newton 1915-1918
Donald W. Nyrop 1951-1952
Ralph A. Ofstie    1953-1955

Ernest M. Pace, Jr.  1943-1944
Mason M. Patrick  1921-1927
Carl J. Pfingstag  1955-1957
Edward M. Powers  1945-1949
Henry C. Pratt  1930-1935
John D. Price  1948-1950
Michael I. Pupin  1915-1922
Donald L. Putt  1949-1958
James T. Pyle  1957-1958

Donald A. Quarles  1954-1956

Arthur W. Radford  1946-1947
Arthur E. Raymond  1946-1956
Samuel Reber  1915-1916
Francis W. Reichelderfer  1939-1958
Delos W. Rentcel  1948-1951
Holden C. Richardson  1915-1917
Lawrence B. Richardson  1944-1946
Edward V. Rickenbacker  1956-1958
Augustine W. Robins  1935-1939
Louis S. Rothschild  1955-1958
Oswald Ryan  1954

Wallace C. Sabine  1918
Gordon P. Saville  1950-1951
George P. Scriven  1915-1917
Carl Spaatz  1946-1948
George O. Squier  1916-1918
Leslie C. Squier  1946-1947
Samuel W. Stratton  1915-1931

David W. Taylor  1917-1938
John H. Towers  1917-1919
1929-1931
1939-1942
Nathan F. Twining  1954-1957

Hoyt S. Vandenberg  1948-1950
Eugene L. Vidal  1933-1937

Charles D. Walcott  1915-1927
Edward P. Warner  1929-1945
William Webster  1950-1951
Oscar Westover  1936-1938
Alexander Wetmore  1945-1952
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### APPENDIX D

**NACA APPROPRIATIONS, 1915-1947**

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**APPENDIX E**

LANGLEY EMPLOYEE GROWTH, 1919-1947

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APPENDIX E

LANGLEY ENGINEERS-IN-CHARGE

Leigh M. Griffith 1920-1926

Henry J. E. Reid 1926-1960

Floyd L. Thompson 1960-present
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Melvin N. Gough, September 14, 1967, Washington, D. C.
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Axel T. Mattson, many dates, Hampton, Virginia.

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