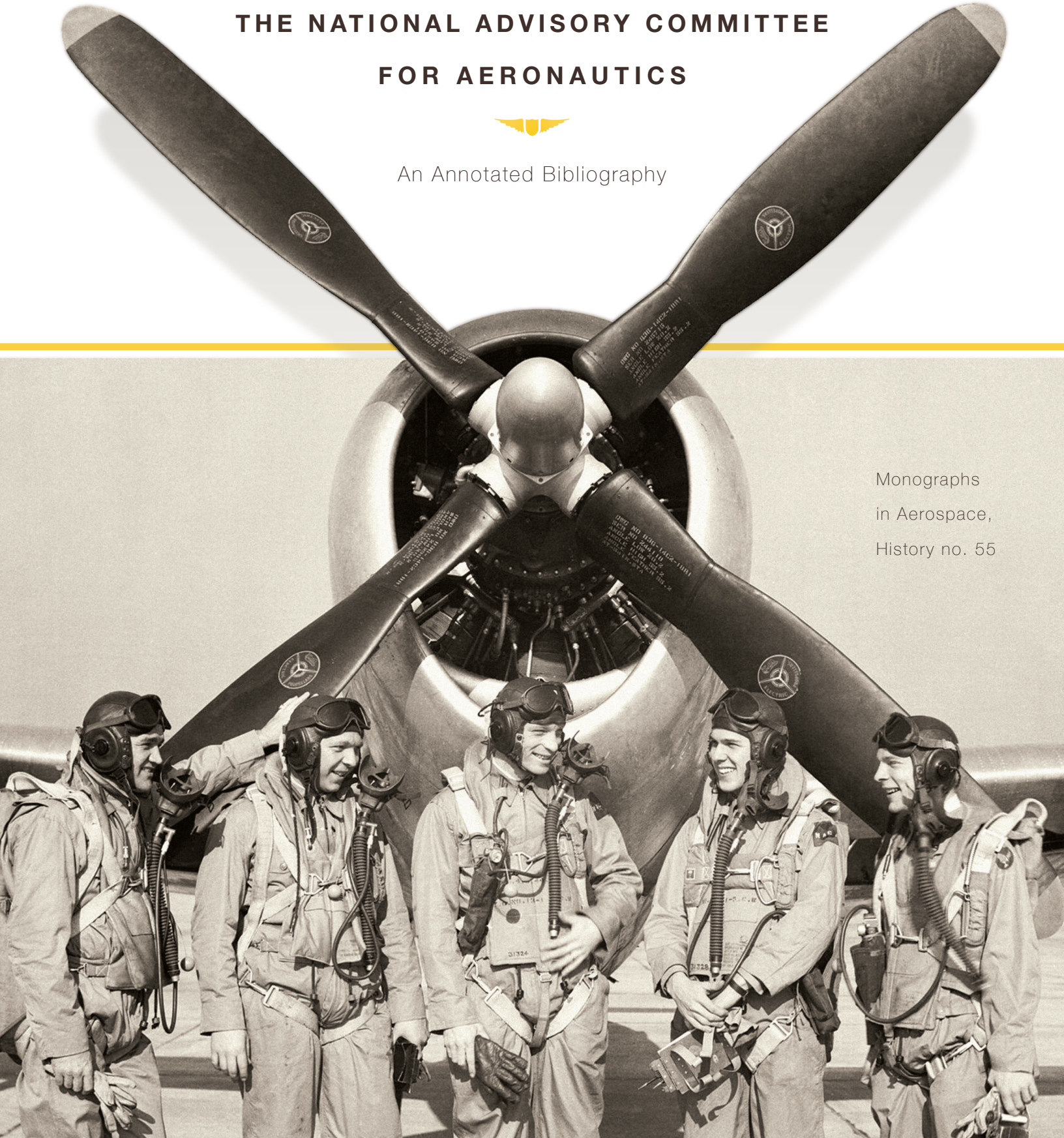
National Aeronautics and Space Administration

THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

An Annotated Bibliography



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FRONT COVER IMAGE:

Image no. A-6786

Test pilots with P-47 Thunderbolt Fighter — Description: Test pilots (from left) Mel Gough, Herb Hoover, Jack Reeder, Steve Cavallo, and Bill Gray stand in front of a P-47 Thunderbolt Fighter in this 1945 photo at Langley.

THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS: AN ANNOTATED BIBLIOGRAPHY

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PREFACE

This annotated bibliography is a compilation of monographs, journal and newspaper articles, and congressional hearings that chronicle milestones in the history of the National Advisory Committee for Aeronautics (NACA). In March 1915, as part of Public Law No. 63-271, the FY 1916 Naval Service Appropriations Act, Congress authorized the establishment of an Advisory Committee for Aeronautics. At its first full meeting one month later, "the Committee added 'National' to its designation," and it would eventually be known as the NACA.[1] The NACA would have 12 members who served without compensation. Under the authorizing statute, the NACA's mission would be "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 1958 the newly established National Aeronautics and Space Administration (NASA) incorporated the NACA's facilities, personnel, and research activities, and the NACA ceased to exist.

The material in this bibliography is arranged according to theme, as follows: airplane industry cooperation, awards, establishment of laboratories and new facilities, historical overview, inter-agency cooperation, international cooperation, the NACA's board composition, the NACA's early years, the NACA's relations to NASA, and the NACA's technology and research. The entries contained in each of these sections are arranged chronologically. A glossary of NACA abbreviations is also included. The researchers compiled the contents of this bibliography from a number of journal publications and newspapers, including *Air Power History*; *Aviation*; *Aviation and Aeronautical Engineering*; *Aviation and Aircraft Journal*; *Baltimore Sun*; *Hartford Courant*; *Journal of Aeronautical Sciences*; *Journal of Air Transportation*; *New York Times*; *Science, Technology and Culture*; *and Washington Post*. Relevant congressional hearings are included as well. Researchers accessed a number of databases to identify the resources in this bibliography, including Ebsco, Gale Cengage, JSTOR, Lexis, ProQuest (including ProQuest Science, ProQuest Congressional, and WorldCat). They also consulted the Web sites of the American Institute of Aeronautics and Astronautics (AIAA), Cranfield University's Aerade Reports Archive (which incorporates digitized reports from the Aeronautical Council (Great Britain) and the NACA), the European Conference for Aero-Space Science, NACA 90th Anniversary Web Site (http://history.nasa.gov/naca/pubs.html), NASA Technical Reports Server (NTRS), available at http://ntrs.nasa.gov or at http://naca.central.ac.uk, and the United Kingdom's Ministry of Supply.

Since this bibliography focuses on sources not published by NASA or the NACA, a few words about relevant NASA History sources are in order. The primary source in the NASA History Series about the NACA is certainly Alex Roland's *Model Research: The National Advisory Committee for Aeronautics, 1915–1958*. Pamela Mack's *From Engineering Science to Big Science: The NACA and NASA Collier Trophy Research Project Winners* provides excellent overviews of the five NACA projects which won this prestigious award and also provides a solid

[1] Gerald Johns, "Dictionary Making by Conference and Committee: NACA and the American Aeronautical Language," *Journal of the American Society for Information Science* 35, no. 2 (March 1984): 75; Johns quotes Alex Roland, "The National Advisory Committee for Aeronautics," *Prologue* 10, no. 2 (Summer 1978): 69–81.

underpinning for discussions of NASA's research culture. Other notable NASA History Series books such as James Hansen's *Engineer in Charge: A History of the Langley Aeronautical Laboratory, 1917–1958 and The Wind and Beyond: Journey into the History of Aerodynamics in America, Volume 1, The Ascent of the Airplane* are potentially rich sources for those researching the NACA. Other Field Center histories of the NACA may also be useful. A complete list of the NASA History Series with links to full-text versions is at http://history.nasa.gov/series95.html online.

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ABBREVIATIONS

AGARD	Advisory Group for Aeronautical Research and Development (for NATO)
AIAA	American Institute of Aeronautics and Astronautics
CAA	Civil Aeronautics Administration
DOD	Department of Defense
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBS	National Bureau of Standards
NTRS	NASA Technical Reports Server
OPI	Office of Public Information
PAC	Personal Aircraft Council
USAAF	U.S. Army Air Force
VDT	Variable Density Wind Tunnel

AIRPLANE INDUSTRY COOPERATION

New York Times. "Experts To Consider Mechanics of Flying." 11 May 1929. This article describes plans for the upcoming fourth annual aircraft-engineering research conference sponsored by the NACA, which would take place at the Langley Memorial Aeronautical Laboratory. The conference presentations would include an analysis of the NACA's investigations into cowling and cooling problems; distribution of aerodynamic loads on wing surfaces, tail surfaces, and fuselage; efficiency of propellers; and issues related to tailspin and various methods of absorbing landing shock.

New York Times. "Startling Devices Aid Plane Research." 14 May 1930. This article relates the events of the NACA's "fifth annual aircraft engineering research conference." At the conference, the NACA's chief engineers addressed approximately 200 representatives of the U.S. Army, the U.S. Navy, the U.S. Department of Commerce, and the airplane-manufacturing industry, describing the work that the NACA had conducted during the previous year. The NACA presented to the audience a wind tunnel that could generate wind speeds of 900 mph, a glass observation window placed in an airplane's engine cylinder, and a manometer that records the actions of airplane parts during flight. However, despite the aeronautic advances that the NACA's researchers displayed, conference attendee W. S. Stout, of the Ford Company, complained that the public's failure to purchase airplanes for personal use showed that aviation had not progressed during the previous two years. Aviation pioneer Igor Sikorsky, founder of Sikorsky Aircraft Company and creator of the world's first mass-produced helicopter, also attended the conference.

"The National Advisory Committee for Aeronautics." *Science* 74, no. 1,923 (6 November 1931): 451. This article reports that, on 22 October 1931, the NACA made the Langley Field Laboratory's facilities available for use by private aircraft manufacturers, with the following conditions: the manufacturer must agree to pay the NACA's expenses; Langley Field Laboratory must be the only facility capable of performing the experiments that the manufacturer required; and the manufacturer could publish the test results only at the discretion of the NACA. The article also lists the names of the members elected as chair, vice chair, and to the executive board of the NACA.

Cleveland, Reginald M. "Along the World's Airways: Ways Blazed for Air Gain." *New York Times*, 14 May 1933. This article summarizes a meeting held at the NACA's Langley Field Laboratory and attended by nearly 200 aircraft industry engineers and executives. Presenting to their guests the previous year's developments at Langley Field, the NACA's staff engineers emphasized the practical work performed at the NACA's Langley Field Laboratory, rather than the laboratory's theoretical studies. The NACA's guests watched a smoke-tunnel model demonstrate how a better fit between the fuselage and wing improved the airplane's aerodynamic efficiency. The NACA's researchers also described how adjusting the placement of external ailerons improved aerodynamic efficiency. The NACA's engineers said that, unless engineers could find a more efficient way to move heat away from an aircraft's engine, air-cooled engines were nearing their horsepower limits.

Cleveland, Reginald M. "Planes Are Tested at 500-Mile Speed." *New York Times*, 21 May 1936. This article describes the NACA's 11th annual engineering conference, in which participants described the NACA's research efforts of the previous year. Nearly 300 leaders in aviation were at Langley Field to attend presentations about engine development and to see the wind tunnel that could generate speeds as high as 500 mph for aircraft tests. The wind tunnel's 8,000-horsepower electric motor, which drove the 18-blade propeller that created the tremendous wind, was also on display. The wind tunnel was equipped with counter vanes to prevent air twisting in the tunnel and with cooling devices to neutralize the heat that the electric motor generated.

Lubell, Samuel. "Exhibits at Langley Field Like Circus of Progress." *Washington Post*, 24 May 1936. This article reports activities at the NACA's 11th annual aircraft engineering conference. Those attending noticed a change in focus from previous NACA conferences. The NACA's priorities had shifted from experimental flights to research performed in wind tunnels with model aircraft. For example, visitors saw a low-wing monoplane model failing a free-spin test in the free-spinning tunnel, and later watched the same airplane pass the test, once engineers had added more fin area. The visitors also watched demonstrations of the NACA's research on landing gear, propellers, and nose-slot cowling.

Washington Post. "Dust, Rivets Slow Down Ships' Speed." 23 May 1937. At a gathering of aviation experts and engineers, the NACA's Langley Field Laboratory presented its achievements, including the development of powerful engines, improved aerodynamics, and a new wind tunnel. The NACA had developed new engine cowlings, with a nose slot that airplane pilots could adjust to allow more cooling air to flow over radial engines during takeoff and climbs, alleviating serious overheating problems. Furthermore, the NACA's engineers had determined that smooth flight surfaces were better than surfaces with rivets. They had discovered that even small rivet heads protrude, producing air resistance and sapping the horsepower required to propel large, fast airplanes. In addition, Langley Field Laboratory now had the only wind tunnel in the world featuring free flight—a model airplane could now fly in the wind tunnel unattached to the tunnel, using its own ailerons and rudder to control its flight.

Baltimore Sun. "New Plane Speeds Forecast by NACA." 11 February 1946. This article reports the Aviation Writers Association's recent tour of Langley Field Laboratory's facilities. During World War II, the NACA had imposed a "cloak of secrecy" over its facilities, curtailing such visits, but during the recent tour, the NACA's officials showed reporters commercial and military experiments and facilities. The writers saw air shock waves over the leading edge of a wing exposed to 1,000 mph wind velocity. In addition, they watched as a machine press capable of exerting 600 tons of pressure tested the structural strength of an aluminum alloy compound. They also observed a seaplane pontoon catapult into a 2-foot-tall wave to test its durability. Finally, the NACA's officials offered the reporters a forecast of the future, suggesting that, within three years, mail planes would fly at 1,000 mph and seaplanes would fly at 300 mph.

Wall Street Journal. "Personal Plane Council Rejects Research Plan Offered by Government." 23 June 1947. This article reports that the Personal Aircraft Council (PAC) of the Aircraft Industries Association rejected a proposal by the U.S. Department of Commerce and the Civil Aeronautics Administration (CAA) to develop a low-cost personal airplane. The CAA administered and regulated civil aviation, and the NACA performed aviation research and development. The PAC rejected the offer because the proposed research would duplicate the NACA's research. According to the PAC, the CAA's proposal violated statutory allocation of funds and duplicates functions.

Nelson, Richard R. "Government Support of Technical Progress: Lessons from History." *Journal of Policy Analysis and Management* 2, no. 4 (Summer 1983): 499–514. According to this article evaluating the role of government research funding in support of technical progress, between World I and World War II, the NACA successfully conducted government-funded basic aviation research. Aircraft manufacturers applied the NACA's basic research results to their own designs and achieved technical progress in specific aeronautical designs for aircraft. After World War II, the NACA's role became redundant because the armed services paid contractors to perform the basic research that the NACA had previously performed.

AWARDS

New York Times. "Hoover Presents Collier Air Trophy." 4 June 1930. This article reports President Herbert Hoover's presentation of the Robert J. Collier Trophy to the NACA. The award is given "for the greatest achievement in aeronautics in America, with respect to improving the performance, efficiency, and safety of air or apace vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year." The president presented the award to NACA Chair Joseph S. Ames in recognition of the NACA's development of "the means of cowling the radial air-cooled engine so that the resistance, or drag, is greatly reduced." The cowling enabled "a stream-lined airflow over the fuselage increasing the speed of the airplane by fifteen to twenty miles per hour."

Cleveland, Reginald M. "Dr. Ames Receives Langley Medal." *New York Times*, 22 May 1935. U.S. Supreme Court Chief Justice Charles Evan Hughes presented NACA Chair Joseph S. Ames with the Langley Medal for Aerodynamics, in recognition of his work to make American aircraft some of the finest in the world. The presentation was made at the Smithsonian Institution, of which Justice Hughes was chancellor of the Board of Regents. This occasion was only the sixth time a person had received the medal in 27 years. Wilbur and Orville Wright had won the award in 1909. Ames gratefully accepted the award in the name of the NACA and the NACA's engineers.

New York Times. "Aeronautical Research." 13 May 1936. This short article announces that NACA Director George W. Lewis had received the 1936 Daniel Guggenheim Award, for his leadership of technical achievement in the field of aeronautical research, methods, and equipment. The author of the article warned that the United States needed to engage in even more aeronautical research to remain ahead of France, Germany, Great Britain, and

Italy. Although the United States had previously achieved a three-year lead over these countries in technical research, the gap had since closed to an estimated 18-month lead.

Washington Post. "Rodert To Receive Aviation Award: NACA Engineer Wins Collier Trophy for Heat Method To Prevent Icing." 11 December 1947. This short article announces that Lewis A. Rodert, Chief of Flight Operations at the NACA's Flight Propulsion Research Laboratory in Cleveland, Ohio, won the Robert J. Collier Trophy for his work on airplane deicing. Rodert had developed a method of directing hot engine-exhaust gases to the leading edges of the airplane wings. Heating the wings prevents the formation of ice on the wings' leading edges, which makes an airplane difficult for a pilot to control during flight. President Harry S. Truman would award the trophy to Rodert on 17 December 1947, in a ceremony at the White House.

New York Times. "The Guggenheim Medal." 5 December 1950. This article reports that the American Society of Mechanical Engineers, the Institute of the Aeronautical Sciences, and the Society of Automotive Engineers have awarded the 1950 Daniel Guggenheim Medal to NACA Director Hugh L. Dryden. The Guggenheim award for "outstanding leadership in aeronautical research and fundamental contributions to aeronautical sciences" recognized Dryden's work concerning the "boundary layer," properties of airfoils at high speeds, turbulence, and wind pressure on structures, as well as his research on problems associated with flight at speeds near and faster than the speed of sound.

Mack, Pamela E., ed. *From Engineering Science to Big Science: The NACA and NASA Collier Trophy Research Project Winners*. NASA SP-4219. Washington, DC: NASA, 1998. This book, a publication in the NASA History Series, presents a series of case studies of "notable technological projects carried out at least in part by the NACA and NASA," from 1929 through 1994. Each of these projects won the National Aeronautic Association's Collier Trophy, awarded for "the greatest achievement in aviation in America, the value of which has been thoroughly demonstrated by use during the preceding year." The first chapter of this work focuses on the 1929 Collier Trophy awarded to the NACA for its development of a low-drag engine "cowling." The NACA based its design of the cowling on the premise that, rather than leaving the engine's cylinders open to the air, covering up "the cylinders of an air-cooled radial engine could not only dramatically reduce aerodynamic drag but actually improve engine cooling." Other early chapters of this book illustrate the central role of critical issues such as supersonic flight research, construction of the transonic wind tunnel, and development of thermal de-icing, challenges that the NACA confronted in the years before, during, and after World War II. The necessity of achieving practical results to justify federal funding, coupled with "the dominant role of engineers on the NACA main committees" caused the NACA's leadership to reverse its former opinion that the NACA "had to establish its reputation by scientific (not engineering) achievement." According to editor Pamela E. Mack, this transformation of the NACA's mindset "established the relationship between theoretical and practical research as a central tension within the laboratory and for the agency as a whole."

ESTABLISHMENT OF LABORATORIES AND NEW FACILITIES

Baltimore Sun. "Big Wind Tunnel To Test Airplanes Put into Operation." 28 May 1931. This article announces the first day of operations for the NACA's wind tunnel and seaplane-towing channel at Langley Field—the largest wind tunnel and the largest seaplane-towing channel in the world. The 60-foot-by-30-foot wind tunnel, driven by two 4,000-horsepower engines, allowed for testing full-size airplanes at wind speeds up to 115 mph. The NACA planned to use the 2,040-foot-long, 24-foot-wide, 12-foot-deep channel to test flying boat hulls for efficiency.

New York Times. "Wind Tunnel Will Be Built at Langley Field To Test Speeds up to 500 Miles per Hour." 19 July 1934. This short article announces a new $478,300 wind tunnel at Langley Field Laboratory. The wind tunnel's 8,000-horsepower engines propelled winds at speeds up to 500 mph in the 8-foot-wide wind-tunnel test chamber. The NACA's researchers intended to use the tunnel to explore, safely and reliably, airflow exceeding 200 mph, in order to improve the performance of American commercial and military airplanes. The NACA's engineers planned to use the wind tunnel's test results to "assure superior performance for American military and commercial aircraft."

Cleveland, Reginald M. "Aviation Experts To Test Air Tunnel." *New York Times*, 20 May 1936. This article cites the NACA's new high-speed wind tunnel at Langley Field Laboratory, capable of producing wind speeds of 500 mph, as the largest wind tunnel in the world. The NACA intended to demonstrate the tunnel to 300 aeronautics leaders the following day. The NACA engineers also planned to exhibit diesel engines developed to provide greater fuel efficiency, which would allow for increased airplane payloads, as well as design improvements to flying boat hulls and pontoons, developed in Langley's 2,500-foot-long test basin.

Crider, John H. "May Widen Base: Need of Expanded Research Program Is Outlined to Congress by N.A.C.A." *New York Times*, 19 February 1939. According to this article, the NACA had made the U.S. Congress aware of the dominance of air power in foreign affairs and the importance of funding aeronautical research, so that the United States could keep pace with the aeronautical research activities of foreign countries. In response, the House Appropriations Committee recommended that part of the 1940 NACA appropriation go to a two-dimensional wind tunnel, which reduces wind-tunnel turbulence, and to upgrades to the propeller tunnel.

Chicago Tribune. "Report Rouses Hope of Chicago Air Laboratory." 9 January 1940. This article reports the U.S. Congress's interest in building a new NACA research laboratory in the Midwest. U.S. Representative Ralph E. Church (R-IL) declared that the NACA should build its third laboratory, a new airplane-engine laboratory, near Chicago, Illinois. The NACA considered a laboratory dedicated to engine research of utmost importance. Late in 1939, the Special Survey Committee on Aeronautical Research Facilities, chaired by Charles A. Lindbergh, had reported to the NACA, "American facilities for research on aircraft power plants are inadequate and cannot be compared with the facilities for research in other major fields of aviation." Church claimed that Chicago, and its nearby

vicinity, was safe from foreign attack by air or by sea, unlike the NACA's first laboratory in Langley, Virginia, or its second laboratory at Moffett Field near San Francisco, California. Church and other members of the U.S. Congress had failed to persuade the NACA to build its second laboratory in the Midwest.

New York Times. "For Engine Research." November 30, 1940. This article reviews NACA Chair Vannevar Bush's announcement that the NACA planned to build a new facility for engine research at the Cleveland, Ohio, municipal airport. During the previous June, the U.S. Congress had appropriated $8.4 million for the facility, which would be the NACA's third major center for aeronautical research. The NACA's two existing centers at Langley Field and Moffett Field were chiefly devoted to aerodynamics. A special committee on research facilities had determined that addressing the lack of existing facilities for engine research was critical to the development of aviation, in general, and to the U.S. defense program, in particular. According to NACA Research Director George W. Lewis, "the engine is the heart of the airplane."

Los Angeles Times. "World's Record Wind Tunnel Being Built in California." 11 July 1941. This short article describes the wind tunnels under construction at the new Ames Aeronautical Laboratory. Although the article does not indicate how many tunnels the NACA intended to build at Ames Laboratory, it mentions that one wind tunnel featured 44-foot fan blades, and another could generate wind speeds up to 600 mph. A wind-tunnel control board would provide operators with airplane-performance readings. The engineer in charge of the facility, Smith J. DeFrance, believed that the completed wind-tunnel test facilities would compare favorably with those of Germany. The $10 million laboratory was under the constant guard of the U.S. Army.

Wall Street Journal. "$20 Million Aircraft Engine Laboratory Now 95% Complete." 20 May 1943. This article, published on the day of the dedication of a new NACA engine-research laboratory in Cleveland, Ohio, describes the new facility. The 12 buildings of the research complex had combined floor space of more than 10 acres, and the laboratory would draw an electrical load of 109,160 horsepower. The laboratory's engine-research wind tunnel, which had the highest horsepower rating of any wind tunnel built to date, could generate wind speeds of 500 mph. It would feature refrigeration, to allow engineers to test engines at -67°F, the air temperature common at 50,000 feet above Earth.

Davies, Lawrence E. "New Wind Tunnel in Operation; Tests Performance of Big Planes." *New York Times*, 9 June 1944. This article describes the world's largest wind tunnel, dedicated the day this article appeared. The wind tunnel, located at the NACA's Ames Laboratory at Moffett Field in California, could hold full-size fighter planes as large as medium-size bombers. The facility had three smaller wind tunnels and various laboratories for the study of aeronautics. The large wind tunnel had six 6,000-horsepower electric motors. Devices in the tunnel could measure up to 180,000 pounds of lift force and 32,000 pounds of drag force to assist engineers in detecting and correcting problems.

Christian Science Monitor. "Plane Put Through Rigid Tests; Huge Wind Tunnel To Aid Mastery of Air." 26 December 1944. Officials at Ames Aeronautical Research Laboratory

announced that, on 8 June 1944, the NACA had opened its largest wind tunnel to date. The wind tunnel was 40 feet tall by 80 feet wide and could accommodate a full-sized airplane. Six 40-foot propellers generated wind-tunnel air velocity, with speeds up to 200 mph. The structure containing the wind tunnel covered an area of 8 acres.

New York Times. "New Wind Tunnel in California Is Hailed as 'Most Versatile' Air Research Facility." 17 July 1946. This article reports that several hundred military officers and aircraft manufacturers toured the Ames Aeronautical Laboratory, where they saw the NACA's newest $3.3 million wind tunnel. The NACA officials displayed the versatile wind tunnel, which created wind speeds as fast as the speed of sound and produced air pressures measuring from one-sixth the pressure of sea level to six times atmospheric pressure. A series of eight fine-mesh wire screens placed before the wind tunnel's test chamber negated almost all of the air-stream turbulence within the chamber, creating an environment similar to that of Earth's outer atmosphere. The manufacturers also viewed a pair of supersonic wind tunnels measuring 1 foot by 3 feet: one of the tunnels could produce wind velocity up to 1,700 mph, and the other could produce wind velocity up to 2,600 mph.

U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee No. 3. *Subcommittee Hearings on H.R. 3434, To Promote the National Defense by Authorizing a Unitary Plan for the Construction of Transonic and Supersonic Wind-Tunnel Facilities and the Establishment of an Air Engineering Development Center*. 81st Cong., 1st sess., 11 April 1949. This hearing includes a brief statement by NACA Executive Committee Vice Chair Francis W. Reichelderfer in support of legislation to authorize a unitary plan for the construction of transonic and supersonic wind tunnels. This legislation became Public Law No. 81-415, the Unitary Wind Tunnel Plan Act of 1949. Reichelderfer emphasized the "pressing and immediate need for these wind tunnels—over and above the normal growth of [the NACA's] research facilities—arising from the revolutionary changes in aeronautical science inaugurated by the development of the turbo-jet engine and other forms of jet propulsion at the close of the last war, and the attainment of flight at speeds greater than the speed of sound." He testified that the NACA and the U.S. military establishment had coordinated their recommendations, developing a unitary plan for the provision of supersonic wind-tunnel facilities, and that the President's Air Policy Commission and the Congressional Aviation Policy Board strongly supported this plan. In conclusion, Reichelderfer stated that the "NACA feels that the urgency and importance of the plan justify expeditious approval in the national interest."

U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee No. 3. *Subcommittee Hearing on H.R. 5074, To Promote the National Defense by Authorizing Specifically Certain Functions of the National Advisory Committee for Aeronautics Necessary to the Effective Prosecution of Aeronautical Research, and for Other Purposes*. 81st Cong., 2nd sess., 20 February 1950. This hearing includes the testimony of NACA Chair Jerome C. Hunsaker in support of legislation authorizing the equipment, maintenance, and operation of the present facilities; additional land, construction, and equipment at the present facilities; transfer of certain materials to the NACA by the U.S. Department of Defense (DOD); and the change of name of the laboratory at Cleveland,

Ohio, to Lewis Flight Propulsion Laboratory. This legislation became Public Law No. 81-672. Included in the body of this hearing was the text of the National Aeronautical Research Policy, as revised and approved on 21 March 1946. According to Hunsaker, this written agreement among the aircraft industries, the military services, the CAA, and the NACA "clearly recognizes their respective roles" and prevents "unnecessary overlapping and duplication of effort."

Graham, Frederick. "2 Tunnels Solving Air Speed Enigmas." *New York Times*, 19 May 1951. This article describes the development of two new transonic wind tunnels at the Langley Aeronautical Laboratory. The tunnels, measuring 16 feet and 8 feet in diameter, respectively, were unique in their ability to study flight and to provide accurate aerodynamic data throughout the transonic range, which is the speed range between subsonic and supersonic speeds. In the transonic range, airplanes experience buffeting and pitching, and in some instances, their controls operate in reverse. According to Langley's chief of research, building these tunnels would enable the NACA to "meet the demands for the mass of fundamental technical information required for the design of tomorrow's high-speed airplanes."

New York Times. "Wind Tunnel To Give Supersonic Blasts." 12 October 1951. This short article describes the NACA's plans to use electric motors to propel air in a wind tunnel at the Lewis Flight Propulsion Laboratory in Cleveland, Ohio. The 250,000-horsepower motor was capable of producing up to 300,000 horsepower for up to one hour. The seven-drive motors would each weigh 120 tons. Together, they would generate a wind-tunnel air speed exceeding 2,750 feet per second (1,875 mph).

U.S. Congress. Senate. Committee on Armed Services. *Hearings on National Advisory Committee for Aeronautics Construction Program*. 83rd Cong., 1st sess., 30 April 1953. This hearing presents the testimony of NACA Director Hugh L. Dryden in support of legislation authorizing construction of equipment at Ames Aeronautical Laboratory, Langley Aeronautical Laboratory, and the pilotless aircraft station in Wallops Island, Virginia. Describing plans for the future, Dryden explained that the NACA intended "increasing the speed capabilities of equipment" at these facilities, which were already in operation and staffed. Dryden discussed at length the operations of the unitary plan for construction of wind tunnels, a plan "adopted for the purpose of providing the large-scale supersonic wind tunnel equipment which forms the basis for investing millions of dollars in prototype supersonic aircraft." He also reviewed modification specifications and costs associated with the large, supersonic wind tunnels under construction, and discussed the NACA's budget for research and development.

U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee No. 3. *Subcommittee Hearings on H.R. 8675, a Bill To Promote the National Defense by Authorizing the Construction of Aeronautical Research Facilities by the National Advisory Committee for Aeronautics Research Necessary to the Effective Prosecution of Aeronautical Research*. 84th Cong., 2nd sess., 14 February 1956. At this hearing, NACA Director Hugh L. Dryden testified in support of legislation authorizing additional construction and installation of additional equipment at three locations: Ames

Aeronautical Laboratory, Langley Aeronautical Laboratory, and Lewis Flight Propulsion Laboratory. According to Dryden, the proposals reflected "the advances of aeronautics toward higher speeds and higher altitudes." Ames Aeronautical Laboratory would make improvements to an existing transonic wind tunnel and to an atmosphere-entry simulator. Langley Aeronautical Laboratory would extend the speed capabilities of one of the wind tunnels constructed under the unitary plan, install a data-processing system, and increase the utility of an existing wind tunnel. The Lewis Flight Propulsion Laboratory would make improvements to its propulsion-systems laboratory and install a disposal system for combustion waste products.

Hansen, James R. *Engineer in Charge: A History of the Langley Aeronautical Laboratory, 1917–1958*. NASA SP-4305. Washington, DC: NASA, 1987. This well-written history of the "mother Center" covers its organizational culture, key personalities, as well as its technical successes and challenges.

HISTORICAL OVERVIEW

Gray, George W. *Frontiers of Flight: The Story of NACA Research*. New York: Alfred A. Knopf, 1945. This book describes the NACA's early years, growth, and research. The author describes efforts undertaken to authorize the establishment of the NACA and how the NACA successfully organized and conducted research through committees and teamwork. The NACA conducted research focused on three aeronautical topics: airflow, propulsion, and structure. The author also describes test facilities and tools that the NACA used to conduct its research, for example, the NACA's various wind tunnels and how they operated. Unique to this book is the extensive description of seaplane design and research. The NACA conducted seaplane research in large basins designed and constructed solely for this purpose. The towing basin worked much like a wind tunnel to test water resistance experienced during takeoff and landing. In addition, the author describes the problems that arise with increased air speed, such as flutter, vibration, and compression, as well as devices that the NACA developed to overcome these problems. The book also describes transonic and supersonic airplane designs, piston and jet engine propulsion, propeller research, and wing loads. The book includes both illustrations and pictures of the NACA's facilities and research, as well as an appendix listing the NACA's chairs and members.

United States. Library of Congress. Legislative Reference Service. *Policy Planning for Aeronautical Research and Development. Staff Report*. Washington, DC: U.S. Government Printing Office, 1966. The Library of Congress's Legislative Reference Service prepared this U.S. Senate staff report for the Senate Committee on Aeronautical and Space Sciences. The report describes the relationship between national transportation systems and civil aviation, as well as changes in research and development funding sources. It contains a chronology of the NACA's activities, through the establishment of NASA in 1958, and a chronology of the aeronautical research and development performed by the NACA and other agencies. The report contains an appendix, figures, glossary, index, and tables.

Roland, Alex. *Model Research: The National Advisory Committee for Aeronautics, 1915–1958*. 2 vols. NASA SP-4103. Washington, DC: National Aeronautics and Space Administration, 1985. According to the author Alex Roland, this comprehensive work, which begins with "the quest for a national aeronautical laboratory" in 1910, examines the NACA as an institution, attempting "to explain how and why it functioned and to evaluate it as a research organization." The book is not a technical history, but rather "a political and institutional history focusing on the NACA as a model research organization." Roland views his work as both a narrative history "and a reference work from which the essential facts of the Committee's history can be readily retrieved." The primary sources for this work are records from the NACA's headquarters, supplemented with data from the NACA's laboratories. Volume two of this work contains extensive documentation supporting the text, including major legislation; documents related to committee structure and composition, and budgets and appropriations; reports resulting from the research process, and selected historical documents.

U.S. Congress. House of Representatives. Committee on Science and Technology. Task Force on Science Policy. *Hearings on Research Funding as an Investment*. 99th Cong., 2nd sess., 29 and 30 April 1986, and 1 May 1986. This hearing includes the testimony of aerospace technology historian Richard P. Hallion, summarizing the accomplishments of the NACA since its inception. Hallion cites in particular the establishment of airfoils, the development of wind tunnels, and "aggressive flight research and testing." He notes that, by the end of the 1930s, the NACA had established the pattern for future aeronautical research—"a partnership of ground research and research aloft, using the sky as laboratory."

Bilstein, Roger E. *Orders of Magnitude: A History of the NACA and NASA, 1915–1990*. 3rd ed. NASA SP-4406. Washington, DC: NASA, 1989. This work, which is part of the NASA History Series, presents a chronological history of the NACA and its successor agency NASA, providing an overview of the events in the United States and abroad that led to the NACA's establishment in 1915. NASA notes in the foreword that recent technological advances make it "easy to forget the extent to which aeronautical research and development—whether in propulsion, structures, materials, or control systems—have provided the fundamental basis for efficient and reliable civil and military flight capabilities." This edition of Bilstein's work "restores aeronautics to its due place" in NASA's history. According to the author, the two recurrent themes of this book are the continuing relationship between the NACA and NASA and the U.S. military services, and the U.S. aerospace community's ongoing interaction with the European aerospace community.

Hetherington, Norris S. "The National Advisory Committee for Aeronautics: A Forerunner of Federal Governmental Support for Scientific Research." *Minerva* 28, no.1 (Spring 1990): 59–80. This article documents the history and significance of the NACA's work as a research institution supported by the government. The article reviews the research efforts of Samuel Pierpont Langley, which began in the 1880s. Langley's many experimental airplane failures resulted in congressional resistance to funding aeronautical research. The U.S. Congress continued to balk at funding aeronautical research until the

establishment of the NACA in 1915. The author notes that, even after its establishment, the NACA had to continue fighting for public and congressional recognition of the need for aeronautical research. However, a turning point came in 1923, when President Calvin Coolidge transmitted to Congress the NACA's annual report, which documented successful experiments that addressed critical aeronautical problems. Coolidge stated that the "United States was gradually forging ahead of other nations in our knowledge of the scientific principles underlying the design and construction of aircraft." This article cites various notable events in the history of aeronautics that increased the public's interest in aeronautical research—for example, Charles A. Lindbergh's flight to Paris in 1927. The author contends that NACA-sponsored research, specifically, the development in 1928 of a new form of cowling for radial-cooled engines, firmly established public support, both for the NACA and for government-sponsored scientific research.

Norris S. Hetherington. "Air Power and Governmental Support for Scientific Research: The Approach to the Second World War." *Minerva* 29, no. 4 (Winter 1991): 420–439. This article documents the NACA's uphill battle to obtain congressional funding for aeronautical research, a battle that continued until World War II broke out in Europe in 1940.

Gorn, Michael H. *Expanding the Envelope: Flight Research at NACA and NASA*. Lexington, KY: University Press of Kentucky, 2001. Tracing the NACA's and NASA's 90-year history of flight research, this recent book takes its title from a pivotal objective of flight research known as "envelope expansion"—identifying the limits of aircraft performance. According to the author, Michael H. Gorn, the essential mission of flight research is to "separate the real from the imagined." The author's research covers a wider landscape than earlier seminal works, which focused on Dryden Flight Research Center. However, in this book, he chooses to explore a few subjects in depth, namely, "the processes of flight research—the evolution of tools, techniques, and organization, for example—rather than the progress of each individual project." Gorn believes that "some projects simply illustrate a type of flight research more effectively than others." He notes several "dividends" paid by flight research, including the systematic discovery of "unexpected and overlooked aeronautical phenomena."

Ramold, Steven J. "National Advisory Committee for Aeronautics." In *Encyclopedia of Flight*, edited by Tracy Irons-Georges. Pasadena, CA: Salem Press, 2002. This encyclopedia article tells the story of the NACA's advances in aeronautical research. U.S. private and government aircraft research declined in the decade following the Wright brothers' flight in 1903, and European designers and manufacturers took the lead in aerospace research. With World War I underway in Europe, the U.S. government realized that it must take steps to reverse this trend. In 1915 the NACA was formed for the purpose of renewing U.S. aeronautics research and helping to design and test advanced aircraft for the U.S. military. Between World War I and World War II, the NACA developed the United States' civilian aircraft market, employing trained test pilots with backgrounds in engineering, and building wind tunnels to research issues of aeronautics design. During the inter-war period, the NACA designed an engine cowling acclaimed for reducing drag and increasing air speeds while maintaining proper temperatures for operating an engine.

To help with the war effort during World War II, the NACA opened a second laboratory, Ames Aeronautical Laboratory, in California, and a propulsion laboratory, Aircraft Engine Research Laboratory, in Cleveland, Ohio. During World War II, the NACA improved bomb-load capacity, endurance, and speed for 18 existing U.S. military aircraft, such as the P-38 Lightning and the P-51 Mustang. After the war ended, the NACA used its wind tunnels to study swept-wing configurations, later applying this concept in the design of the F-86 Sabre. Experiments conducted in the NACA's wind tunnels also led the NACA's engineers to develop designs to overcome wingtip shock waves, which occur as an airplane approaches the speed of sound. The NACA and Bell Aircraft developed the rocket-powered X-1, which became the first airplane to break the sound barrier on 14 October 1947. In the 1950s the U.S. military's multiple rocket programs failed to keep up with the rocket program of the Soviet Union. To improve the quality of the U.S. rocket program, the U.S. military's multiple programs merged with the NACA on 1 October 1958 to form NASA, the agency that would run the U.S. space program.

Trimble, William F. *Jerome C. Hunsaker and the Rise of American Aeronautics*. Washington, DC: Smithsonian Institution Press, 2002. This book relates the life and work of Jerome C. Hunsaker, Chair of the NACA from 1941 to 1956. Hunsaker emphasized basic aeronautical research and transferred European aerodynamic theories to the NACA. "In a career in aviation engineering and air technology that spanned six decades in the classroom, laboratory, and government office, he established himself as one of the leading theorists of flight and aircraft design." Hunsaker joined the NACA as the U.S. Navy's representative in 1922 and served on the Aerodynamics Committee and Materials for Aircraft Committee. He co-authored the NACA's first technical report, helped define the NACA's research agenda "in light of European developments," and collaborated with the organization's members on research projects. The author suggests that one of Hunsaker's major accomplishments was convincing Max M. Munk, a promising theoretical aerodynamicist, to leave the University of Göttingen in Germany and to join the NACA. On 31 July 1941 Hunsaker was elected Chair of the NACA's Executive Committee. In the 1941 Annual Report, submitted in late December of that year, Hunsaker recommended a shift in the NACA's priorities from basic research to "maximizing the performance of military airplanes." After World War II, Hunsaker opposed either folding the NACA into the military or permitting the NACA to compete with private industry. Instead, he promoted the NACA's focus on basic research. Hunsaker pursued "a unified policy of government-industry-military cooperation in aeronautical research." On 21 March 1946 the Army, the CAA, the NACA, and the Navy approved a national aeronautical research policy that defined the NACA's role as "fundamental research in the aeronautical sciences, with the goal of solving the basic problems of flight." Hunsaker promoted a return to basic research in "high speed aerodynamics, stability and control, materials, and turbojet engine." He resigned on 28 September 1956, as the NACA was transitioning from researching aeronautics to astronautics. The book contains bibliography, illustrations, index, and notes.

Bilstein, Roger E. *Testing Aircraft, Exploring Space: An Illustrated History of NACA and NASA*. Baltimore, MD: The Johns Hopkins University Press, 2003. The first three chapters of this book cover the operational functions and aeronautical advances and priorities of the

NACA, from its inception in 1915 until 1958. The author notes that the Soviet Union's successful orbiting of the world's first artificial satellite in 1957 spurred a complete reorganization in the following year of the NACA as NASA, with a new emphasis on astronautics. The author discusses the role of the internationally competitive environment and the need for military aviation as factors in determining the NACA's research agenda, as well as how the NACA interacted with the aviation community. Bilstein notes that the "European connection," including legacies of the World War II era, such as jet engines and swept wings, "has been a persistent subtheme in the evolution of many key programs conducted by both NACA and NASA."

Hansen, James R., editor, with D. Bryan Taylor, Jeremy Kinney, and J. Lawrence Lee. *The Wind and Beyond: A Documentary Journey into the History of Aerodynamics in America; Volume 1: The Ascent of the Airplane*. NASA SP-2003-4409. Washington, DC: NASA, 2003. An excellent reference, this work reproduces key historical documents and also features headnotes and chapter essays putting the documents in context. Volumes one and two have been published and further volumes are forthcoming.

Fletcher, Edward A. "Scramjets and Surfboards: Some Forgotten History." *Journal of Jet Propulsion and Power* 23, no.1 (January–February 2007): 15–20. Prompted by a November 2004 NASA press release announcing that NASA's X-43A had "demonstrated that an air-breathing aircraft can fly at nearly Mach 10," the author of this article recalls that a small group of researchers at the NACA's Lewis Flight Propulsion Laboratory experimented with supersonic combustion in the 1950s. The author notes that these engineers identified the "scramjet"—supersonic combustion ramjet—as an alternative to a rocket or jet engine, discovering that a scramjet could propel hypersonic aircraft through the atmosphere. The article details the research that the author and other researchers at Lewis Flight Propulsion Laboratory performed, beginning in 1952. They based their research on analytical studies "suggesting that combustion under the wing of a supersonic aircraft rather than in the engine would provide more lift than the combustion of an equal amount of fuel in the jet engine."

Gorn, Michael H. "The N.A.C.A. and its Military Patrons During the Golden Age of Aviation, 1915–1939." *Air Power History* 58, no. 2 (Summer 2011): 17–27. This article documents the contentious history of relations between the NACA and the Army, dating back to the departure of the NACA's first Chair, Army Brigadier General George P. Scriven, in 1916. Gorn states that "despite the increasingly frequent and usually productive technical exchanges between the N.A.C.A. and [the Army] during the 1920s and 1930s," the NACA and the Army repeatedly disputed over land holdings and regarding the progress of research projects. By contrast, "the Navy became a trusted ally from the N.A.C.A.'s infancy." Gorn documents the history of two early NACA research projects—engine supercharging and pressure distributions—to illustrate how the "asymmetrical" relationships between the NACA and the Army and the Navy had influenced these projects. Gorn concludes that, by 1939, the Navy "had become not just the N.A.C.A.'s ally, but its mainstay, making 159 formal research requests in the previous 19 years, compared with only 73 for the Army." In the months before World War II, the roles

reversed. Although World War II brought "the N.A.C.A. and its military patrons into closer contact than ever before," tensions still existed between the NACA and the Army.

Gorn, Michael H. "The N.A.C.A. and its Military Patrons in the Supersonic Era, 1940–1958." *Air Power History* 58, no. 3 (Fall 2011): 17–27. According to author Michael H. Gorn, before and during World War II, the chief of the Army Air Corps, Major General Henry H. "Hap" Arnold, "contributed to a continuation of the long history of mistrust between the N.A.C.A. and Army aviation." Gorn documents research into high-speed flight, specifically transonic flight (the transition from subsonic to supersonic speed), to illustrate the sharp differences between Army aviation objectives and those of the NACA and its ally, the Navy. Gorn also discusses at length the role that NACA Director Hugh L. Dryden played in forging compromises between the NACA and the military. Dryden's role in the determination of the location and control of new wind tunnels authorized by 1949 legislation "not only gained the N.A.C.A. the good will of the Air Force, but also a handsome reward of $136 million to build three supersonic and hypersonic wind tunnels at three of its laboratories." Dryden's "profound influence" over the X-15 (hypersonic prototype aircraft) program from 1954 to 1968 led to closer collaboration and reduced tension among the NACA, the Air Force, and its predecessors. Gorn concludes that, "as a consequence, when the N.A.C.A. closed its doors for the last time on September 30, 1958, the new National Aeronautics and Space Administration began with the freedom to establish its ties to the military services unencumbered by the ill-will and intrigues of the past."

INTER-AGENCY COOPERATION

"Work of the National Advisory Committee for Aeronautics." *Science* 47, no. 1,202 (11 January 1918): 37–39. This article describes the NACA's activities during World War I. The NACA cooperated with other federal agencies to design and test airplanes for the war effort. The NACA's engineers and the engineers of the Aircraft Production Board tested the use of steel in airplane construction. The NACA also tested Liberty airplane engines under simulated high-altitude conditions for the National Bureau of Standards (NBS). In addition, the NACA conducted research on the design of airplane carburetors, ignitions, mufflers, and radiators. In 1917 the NACA sent representatives abroad to learn about "scientific matters of importance in connection with the war." The NACA made English and French military flight officers members of the committee so that they could attend the NACA's meetings and contribute the information they had learned regarding European aeronautic research. In 1916 the NACA reviewed several sites and selected a location near Hampton, Virginia, for its first laboratory—Langley Field Laboratory. The NACA then designed the first building for the laboratory and began construction on the site.

D'Orcy, Ladislas. "The New Nomenclature for Aeronautics." *Aviation* 14, no. 16 (16 April 1923): 418–419. This article discusses the recent publication of the NACA's newest "Nomenclature for Aeronautics" (Report no. 157). NACA Chair Joseph S. Ames had chaired the special conference on aeronautical nomenclature that prepared this list of terms. The NACA published the report on nomenclature "with the intention of securing

greater uniformity and accuracy in official documents of the Government and in so far as possible in technical and commercial publications." The author of this article, Ladislas D'Orcy, reviewed what he deemed "outstanding revisions, additions and omissions" in the nomenclature report, but takes particular exception to many of the new terms that it introduces. D'Orcy believed that these new terms were "neither justified on the score of general usage, nor an improvement on those sanctioned in the previous Nomenclature, with which they are often in conflict."

New York Times. "Urges U.S. Retain Supremacy in Air: NACA Recommends Research Policy as Working Guide for Government and Industry." 1 April 1946. This short article reports the NACA's call for defining the roles of the U.S. government and the U.S. commercial aeronautics industry in post-war aeronautical research. The NACA explained that it would conduct fundamental aeronautical research but would not develop specific aircraft or equipment. Instead, the NACA would make its test results available to U.S. industry and the U.S. military, so that they could apply the NACA's findings in their design and development of commercial and military airplanes. The Army and Navy would test military airplanes, and the CAA would test new airplanes and equipment used in civil aviation.

Schubauer, G. B. and H. K. Skramstad. "Laminar Boundry-Layer Oscillations and Stability of Lami**n**ar Flow." *Journal of the Aeronautical Sciences* 14, no. 2 (February 1947): 69–78. This report provides an example of the NACA working with another government agency to advance aeronautical research. In 1940 and 1941, with the cooperation and financial assistance of the NACA, the NBS made a transition from smooth or regular laminar-flow research to turbulent-flow research. In its research, NBS studied the point at which smooth airflow changes to drag. The NBS conducted this research in its own wind tunnel, using a hot-wire anemometer to determine whether small disturbances in laminar flow produced turbulent flow. This research proved that varying velocity fluctuations in boundary layers (the layer where fluid or air molecules will stay or move based upon the movement of a surface) would increase over time and become turbulent. The NACA first published the report as an advanced confidential report.

Johns, Gerald. "Dictionary Making by Conference and Committee: NACA and the American Aeronautical Language, 1916–1934." *Journal of the American Society for Information Science* 35, no. 2 (March 1984): 75–81. This article documents seven reports on aeronautical nomenclature that the NACA published between 1916 and 1934. According to the author, the NACA believed that these reports would establish its credentials "as an authority on aeronautical nomenclature and its definitions," but, in fact, the nomenclature failed to include the "living aeronautical language" contained in "almost every report, note, or memoranda that the NACA issued between 1915 and 1934." The author of this article, Gerald Johns, also faults the Documentation Committee of the North Atlantic Treaty Organization's (NATO's) Advisory Group for Aeronautical Research and Development (AGARD), which published its *Aeronautical Multilingual Dictionary* in 1960. Johns asserts that the Documentation Committee was "no more sophisticated in their approach to defining aeronautical terms than the various conferences and committees of NACA."

Whitford, Ray. "Supersonic Man is Fifty." *Aircraft Engineering and Aerospace Technology* 70, no. 1 (1998): 15. This article describes the differences between the NACA's goals and those of the U.S. Army Air Force (USAAF), regarding transonic research. In 1943 the NACA wanted to use a turbojet-powered vehicle to collect aerodynamic data that it could not acquire using its own wind tunnels. The USAAF wanted to use a rocket to develop higher operating speeds. Concerned with the safety of rocket propulsion, the NACA preferred turbojet propulsion. A turbojet-propelled airplane could fly longer than a rocket and could gather more data. In the end, the USAAF funded the rocket-powered X-1 project, and the NACA developed the layout for all three X-1 airplanes. On 14 October 1947 the X-1 flew at Mach 1.06 and became the first airplane to break the sound barrier in level flight.

Inger, G. R. "The Supercritical Peanut: The Navy's Pioneer in High-Speed Flight Research." *AIAA Journal* 43, no.4 (April 2005): 706–715. This article documents a 1940 project of the NACA and the U.S. Navy Bureau of Aeronautics, the world's first scientific in-flight investigation of supercritical flow around an airplane wing. According to the author, this "well-planned engineering study of compressibility effects" resulted in four significant contributions. "It provided the first flight data for validation of the then-new transonic wind-tunnel airfoil tests at NASA Langley. It validated the proposed method of estimating the critical Mach number of an airfoil. It firmly established the extent of the local supersonic flow pocket on an airfoil at supercritical flight speeds and its Mach number dependence. It focused attention on the controllability aspect of the transonic flight regime by virtue of the aileron rebalancing problem that arose."

Seely, Bruce E. "Editorial Introduction: NASA and Technology Transfer in Historical Perspective." *Comparative Technology Transfer and Society* 6, no. 1 (April 2008): 1–16. This editorial summarizes technology transfer from the NACA to other entities, in the course of the NACA's research activities. The NACA's engineers performed basic aeronautical research using test facilities, such as wind tunnels, that airplane and propulsion companies were unable to duplicate. Therefore, in carrying out its research, the NACA worked closely with representatives of the American military and the American aircraft industry, sharing test results with them. Because of the "shared sense of priorities between researchers and end users," the NACA created "clear channels of communication" with these representatives of the U.S. aeronautics industry and the U.S. military. As a result, a number of commercial and military airplanes incorporated the NACA's research findings in their design and manufacture. For example, commercial and military manufacturers used the NACA's research findings to make faster and stronger military airplanes during World War II.

INTERNATIONAL COOPERATION

Levinson, Mark. "Gleanings from Oft-Neglected Sources: Institutional History from Technical Documents—The Case of the NACA." *Technology and Culture* 28, no. 2 (April 1987): 314–323. This communication to the editor reports historical information that the letter's author, Mark Levinson, discovered in the course of his research on the development and design of airfoil profiles. Examining the NACA's technical reports and the reports of the

NACA's Committee on Aerodynamics for this research, Levinson found that the reports revealed significant nontechnical information, specifically with regard to the NACA's staff. Levinson discusses the "turbulent career" of German immigrant Max M. Munk, an engineer who was a member of the NACA's research staff during the 1920s. Munk proposed and designed the variable-speed wind tunnel, designed a systematic series of airfoils, and authored or coauthored 57 NACA technical reports and technical notes. However, Levinson believes that, because of differences in German and American scientific culture, Munk endured a hostile working environment at the NACA. Munk believed in theoretical research for its own sake, while the American engineers at the NACA were not accustomed to emphasizing mathematical theory. The author notes that inadequate research management at the NACA may have permitted the poor working environment to develop and continue.

Anderson, John David. *A History of Aerodynamics and Its Impact on Flying Machines*. Cambridge: Cambridge University Press, 2005. This book discussing early aerodynamic research and theory includes some sections related to the NACA that highlight the career of German-born NACA theoretical aerodynamicist Max M. Munk. The author describes the tension between NACA officials and Munk regarding the design and construction of the Variable Density Wind Tunnel (VDT) at Langley Field Laboratory. When the VDT opened in 1922, the United States became the undisputed leader in applied aerodynamics for the next 15 years. However, the lack of American college courses in theoretical aerodynamics and mathematics had a negative effect upon the NACA's aeronautical engineering program.

Eckert, Michael. "Strategic Internationalism and the Transfer of Technical Knowledge: The United States, Germany, and Aerodynamics after World War I." *Technology and Culture* 46, no.1 (January 2005): 104–131. This article documents the NACA's work to internationalize aerodynamics research after World War I. At that time, the NACA organized aeronautical intelligence as a peacetime activity, establishing an office in Paris to serve as an overseas base. The NACA used the Paris office to acquire beneficial information about European aeronautical progress. In addition, the NACA collaborated with German aerodynamics experts, specifically, with the Prandtl Institute, in its work on the Göttingen airfoil theory. The NACA later hired German aerospace engineer Max M. Munk, who imparted firsthand knowledge of new aerodynamics research in the University of Göttingen laboratory; however, Munk was unable to assimilate to the NACA's research culture and only stayed at the NACA for six years. According to the author, Munk's difficulties illustrate the differences between German and American research cultures, as well as the larger issue of "the inability of the international community of aeronautical scientists to internationalize and standardize their science."

NACA BOARD COMPOSITION

"The National Advisory Committee for Aeronautics." *Aviation and Aeronautical Engineering* 2, no. 8 (15 May 1917): 346. This article describes the NACA's duties, organization, and subcommittees, and explains its purpose—to direct the scientific study of flight problems. Organized on 23 April 1915, the NACA was established in response to national interest

in aeronautics and spurred by extensive use of aircraft in the war in Europe. The NACA conducted annual elections of a chair, a secretary, an executive committee, and an advisory committee. The NACA's Executive Committee directed the committee's administration and research. The full committee met in April and October each year, and the Executive Committee met monthly. The article enumerates the subcommittees established to facilitate the work of the committee; technical reports issued in the first annual reports; and work in progress at the time of the article's publication, including an investigation of air propellers and the establishment of a field experimental station near Hampton, Virginia.

"N.A.C.A. Reorganized." *Aviation and Aeronautical Engineering* 6, no. 11 (1 July 1919): 579. This article reports that, on 20 May 1916, the NACA's Executive Committee reorganized, creating six subcommittees to implement changes. The six committees were Aerodynamics; Governmental Relations; Materials; Personnel, Buildings and Equipment; Power Plant; and Publications and Intelligence. The article concludes with a list of the subcommittees, followed by the names of the subcommittee chairs and officers. Samuel W. Stratton was a member of four of the six committees and Joseph S. Ames was a member of three committees.

"N.A.C.A. Election." *Aviation and Aeronautical Engineering* 7, no. 7 (1 November 1919): 307. This article announces the results of the NACA's annual election held on October 9, 1919. The committee elected Charles D. Walcott as Chair of the NACA, appointed Joseph S. Ames to the Executive Committee, and appointed George W. Lewis as Executive Officer. The article also enumerates the NACA's functions, such as assisting the president, Congress, the military, and federal agencies with aeronautical inquiries; monitoring the progress of "research and experimental work" of foreign countries, especially Austria, France, Germany, Italy, and the United Kingdom; and researching, investigating, and studying problems "for the advance of the science and art of aeronautics."

U.S. Congress. House of Representatives. Committee on Naval Affairs. *A Hearing on the Bill, Senate 5544, To Increase the Membership of the National Advisory Committee for Aeronautics*. 70th Cong., 2nd sess., 15 February 1929. This hearing includes the testimony of NACA Chair Joseph S. Ames in support of legislation to increase the NACA's membership from 12 to 15 members. The bill stipulated that the three additional members "shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences." Ames included with his testimony a letter that he had written to the Senate Committee on Military Affairs on January 29, 1929. In that letter, Ames stated that, "in view of recent great advances in civil aviation, it is desirable to enlarge the membership of [the NACA] so as to permit the appointment of additional persons from private life who, while broadly acquainted with the needs of aeronautical science, can bring to bear in the discussions before the committee the points of view of the manufacturer of aircraft and the operator of air lines." His testimony supported the addition to the committee of new members who brought a different perspective than that of the current membership.

Hartford Courant. "G. J. Mead Named by Roosevelt." 13 October 1939. This article reports President Franklin D. Roosevelt's appointment of George J. Mead, former Vice President and Chief Engineer of the United Aircraft Corporation, to fill the remainder of Joseph S. Ames's five-year term as a member of the NACA. Ames had resigned because of ill health. President Roosevelt praised Ames for his 24-year NACA membership, during which period he had served as Chair of the NACA or as Chair of the NACA's Executive Committee. The president credited Ames's leadership for the "remarkable progress for many years in the improvement of the performance, efficiency, and safety of American aircraft, both military and commercial."

New York Times. "Men of Research." 24 December 1939. This article announces recent appointments to the NACA. Newly appointed committee member former Brigadier General Walter G. Kilner, a flying officer during World War I, had executive ability that would strengthen the NACA. Reappointments to the NACA included Jerome C. Hunsaker, head of the Massachusetts Institute of Technology's Department of Aeronautical and Mechanical Engineering; engine designer George J. Mead; and Director of Research George W. Lewis. Charles A. Lindbergh had chosen not to continue serving as a member of the NACA but would continue to serve on special assignments.

U .S. Congress. House of Representatives. Committee on Armed Services. *Full Committee Hearings on S. 657, H.R. 5758, S. 1571, and Other Bills*. 80th Cong., 2nd sess., 11 May 1948. This committee proceeding, which was primarily a mark-up session, includes the text of a letter from NACA Chair Jerome C. Hunsaker to the Speaker of the House in support of legislation to increase the membership of the NACA from 15 to 17. Hunsaker stated, "NACA feels strongly the need for two additional members from the ranks of science in order to strengthen the voice of science in the councils of the Committee." In his view, "aeronautical science is entering a new era made possible by the advent of new means of propulsion, and additional scientific members free of governmental or industrial connections are needed to help carry the additional work load and to provide additional potential chairmen."

New York Times. "Dr. Lewis Is Dead: Led Air Research." 13 July 1948. This article announces the death of George W. Lewis, the NACA's former Director of Aeronautical Research, who had resigned the previous year because of failing health. When Lewis started working with the NACA in 1919, the NACA had 16 employees and one wind tunnel. At the time of his death, the NACA had 6,000 employees, 3 large laboratories representing an investment of $100 million, and 40 wind tunnels. Lewis had received many awards, including the 1936 Daniel Guggenheim Medal for outstanding success in the direction of aeronautical research at the NACA.

Boston Globe. "Doolittle Elected NACA Chairman; Hunsaker Retires." 18 October 1956. This short article announces a change in the NACA's leadership, with the resignation of Jerome C. Hunsaker as the Chair of the NACA and the election of James H. Doolittle as his replacement. Hunsaker, who had chaired the NACA for 15 years, was a pioneer in the field of aeronautical dynamics, and Doolittle was a famous civil and military pilot.

U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee No. 3. *Subcommittee Hearings on H.R. 4609, H.R. 674, H.R. 6382, H.R. 230, and H.R. 8392*. 85th Cong., 1st sess., 2 August 1957. This hearing includes the testimony of NACA Director Hugh L. Dryden in support of legislation to include as members of the NACA two representatives of the Department of the Army. According to Dryden, adding the Army to the NACA's membership would recognize "the equal status within the Department of Defense of the Air Force, Navy, and Army by making the Army a party to the considerations of the NACA's programs at the top level as well as on the subcommittees." Dryden also urged the House to adopt legislative language providing specific statutory authority for the NACA to contract for research, a function the NACA had previously exercised under annual appropriation acts.

NACA EARLY YEARS

U.S. Congress. House of Representatives. Committee on Naval Affairs. [Hearing title unknown]. 63rd Cong., 3rd sess., 19 February 1915 (No. 25, statement of Charles D. Walcott, Secretary of the Smithsonian Institution). At this hearing, Charles D. Walcott, secretary of the Smithsonian Institution, responded to the request of the Committee on Naval Affairs asking him to present his views on pending House Joint Resolution 413. The resolution related to the creation of an advisory committee for aeronautics. Walcott referred to his service on a Smithsonian-appointed committee that had conducted a review of this topic, citing the House document that had published the results of that earlier review. According to Walcott, the House document had stated that "the United States was the only first-class nation that did not have an advisory committee for aeronautics and suitable research laboratories placed under its direction." In his testimony, Walcott discussed the merits of having a single committee that could consolidate the research efforts and investigations that other agencies—such as the NBS, the Navy, and the War Department—had already conducted. He pointed out that consolidating these efforts in one committee would create a single line of investigation. Walcott noted specific projects that could benefit from coordinated investigation, such as the testing of Langley's original heavier-than-air flying machine, the development of the biplane and the monoplane, and the development of internal combustion engines for use in aeronautics. Walcott noted that the emphasis of the single consolidated committee would be on the development of flying and experimentation in flying.

U.S. Congress. House of Representatives. Committee on Naval Affairs. *Hearings on Estimates Submitted by the Secretary of the Navy, 1916*. 64th Cong., 1st sess., 21 February 1916 (No. 19, statement of Charles D. Walcott, member of the NACA). At this hearing, Charles D. Walcott, Secretary of the Smithsonian Institution and member of the NACA, testified about the general work of the NACA. Walcott stated that, in its first year of operation, the NACA's executive committee had instituted an "investigation of facilities available in various colleges, technical and engineering institutions and among manufacturers and various aeronautic societies, for the carrying on of aeronautic investigations." Walcott highlighted some major aeronautics investigations that these institutions had accomplished and had reported to the NACA, including breaking of the wires and fastenings of aircraft, control of aircraft during actual operation, development of

aeronautic engines, friction of various surfaces as this applied to flying, and stability of aircraft. In this hearing, the NACA was requesting an appropriation of $85,000 for future expenses, primarily for buildings and equipment. The FY 1916 Naval Appropriation Act, Pub. L. No. 63-271, enacted in March 1915 and authorizing an Advisory Committee for Aeronautics, had appropriated to the Advisory Committee $5,000 per year for five years.

U.S. Congress. House of Representatives. Committee on Naval Affairs. *The Status of Aviation in the United States*. 64th Cong., 2nd sess., 7 December 1916 (No. 13 of the hearings on estimates of the Committee on Naval Affairs, 1916, statements of Charles D. Walcott and Henry D. Souther). At this hearing, one year after the NACA's inception, Charles D. Walcott, Secretary of the Smithsonian Institution and member of the NACA, responded to the request of the Committee on Naval Affairs that he summarize the work that the NACA had accomplished or still had underway. Walcott noted that Congress had not made available to the NACA until August 1916 its second appropriation of $85,000. Therefore, before that date, the NACA had only been able to plan for future investigations. Walcott stressed the coordination of the NACA's work with that of government and industry, pointing out that the Army, the Coast Guard (through the U.S. Treasury), the Navy, the NBS, the Smithsonian Institution, the War Department, and the Weather Bureau all had representatives on NACA's committees and subcommittees, and that the NACA supplemented their expertise with that of its leading academic members from the fields of mechanical engineering and physics. Included with Walcott's testimony, U.S. Army Colonel George O. Squier's report describes the problems that the U.S. military faced in its efforts to develop military aviation and aerostations.

"Senator Borah Wants N.A.C.A. Abolished." *Aviation and Aircraft Journal* 10, no. 26 (27 June 1921): 800. This article discusses the attempt of Senator William Borah (R-ID) to abolish the NACA in 1921. Borah introduced a joint resolution in Congress to abolish the NACA and to transfer its property and duties to other federal government agencies. The resolution claimed that the consolidation of government agencies with overlapping responsibilities and functions was necessary because of the state of the U.S. economy. The resolution called for the transfer of the NACA's duties and technical equipment to the NBS in the U.S. Department of Commerce. Borah proposed to give the NACA's buildings and real estate, as well as its advisory capacity, to the War Department or the Navy.

Cleveland, Reginald M. "Contact." *New York Times*, 25 December 1932. This short article objects to the U.S. government's plan to end the NACA's autonomy and to place it under the oversight of the NBS. According to the author, this attempt to cut costs would stifle the NACA's research and development activities. Working as an independent committee, the NACA had achieved greater aerodynamic efficiency of aircraft, through innovations in cowling, adjustments to engine location, and streamlining of aircraft structure. The NACA's aeronautic achievements had improved aircraft efficiency, performance, and safety, benefitting both commercial and military aviation.

New York Times. "N.A.C.A. Acts Are Praised." 15 January 1933. This article reports that a committee of noted scientists has opposed President Herbert Hoover's plan to place the

NACA under the Secretary of Commerce and to transfer its laboratories to the NBS. The plans for the NACA were part of a larger plan for reorganizing the federal government. Joseph F. Ames, Harry F. Guggenheim, William A. Moffett, Orville Wright, and others signed a report in opposition to the plan, and Charles A. Lindbergh wrote a letter opposing the changes, stating that the proposed "consolidation would reduce the efficiency of the committee."

Longacre, Edward G. "A Place Like No Other." *Air Power History* 44, no. 4 (Winter 1997): 4–18. This article describes site selection, building designs, and construction activity on location at Langley Field Laboratory. The NACA had allied itself with the U.S. Army Signal Corp Aviation Section to create the new facility at Langley Field, a joint effort for civilian and military aeronautical research. The article describes local citizens' efforts to promote their proposed site to the Army Signal Corp. The NACA chose Donn and Deming, a Washington, DC, architectural firm, to design its buildings, and the Army Signal Corp selected Detroit-based architect Albert Kahn for the military buildings. The article describes construction of hangars, laboratories, and roads at the facility for aviation and aeronautical research.

THE NACA'S RELATIONSHIP TO NASA

Washington Post. "NACA in Space." 29 January 1958. This article supports the NACA's proposal to lead the United States' spaceflight programs, arguing that the NACA conducted impressive aeronautical research, operated laboratories with competent staff, and maintained a good working relationship with civilian and military agencies and with industry. The NACA's competitors for spaceflight leadership, such as the Atomic Energy Commission and the U.S. military services, were unable to equal the NACA's achievement in the field. The Atomic Energy Commission lacked experience, facilities, personnel, and working relationships; the difficulties of the U.S. armed forces cooperating with the Russians on space projects precluded their involvement.

U.S. Congress. Senate. Special Committee on Space and Aeronautics. *Hearings on National Aeronautics and Space Act*. 85th Cong., 2nd sess., 6, 7, and 8 May 1958. These hearings, focused on legislation to create NASA, included the testimony of NACA Chair James H. Doolittle, as well as that of representatives of the Atomic Energy Commission, DOD, and branches of the U.S. military. Included with the testimony was the text of the White House memorandum recommending the establishment of NASA, in which President Dwight D. Eisenhower stated that the NACA would "provide the basic organization on which the new Agency will build." Eisenhower also stated that NASA should continue to perform for DOD "services in support of military aeronautics and missiles programs of the type [currently] performed by NACA, and also provide similar services with respect to military space programs." The memorandum provided explicit instructions regarding organizational and operational steps that both the NACA and DOD should take to ensure a smooth transition from the NACA to the new agency, NASA.

"NASA Absorbs NACA." *Science* 12, no. 3,328 (10 October 1958): 826. This short article announces the incorporation of the NACA's facilities, headquarters, personnel, and

research activities into NASA. NASA would rename the three primary laboratories: Langley Aeronautical Laboratory would become Langley Research Center, Ames Aeronautical Laboratory would become Ames Research Center, and Lewis Flight Propulsion Laboratory would become Lewis Research Center. The High Speed Flight Station in Edwards, California, the Pilotless Aircraft Research Station in Wallops Island, Virginia, and Plum Brook Research Reactor Facility in Sandusky, Ohio, would retain their names.

Levine, Arthur L. "The Creations of N.A.C.A. and N.A.S.A." AIAA Paper No. 67-836, American Institute for Aeronautics and Astronautics, New York, 1967. This paper tracing the origins of both the NACA and NASA proposes that the creation of both agencies resulted from the assumption "that the United States was behind other nations in a vital field of technology—and that something had to be done to enable the U.S. to regain its leadership. Thus, both NACA and NASA were new agencies created to deal vigorously with the problems presented by the advance of science and technology." However, different environments and circumstances led to the creation of the two. The political and economic context of the creation of the NACA in 1915 was vastly different from the context of NASA's establishment in 1958, and the U.S. government's role in research and development had also changed. Levine documents the events leading to the NACA's establishment in 1915, including the role of the executive and legislative branches of the federal government. He cites three motivations for the creation of the NACA: the scientific community's concerns that the United States was relatively inferior to other countries in the field of aeronautical science; the military implications of a national aeronautical establishment; and the commercial implications of aviation, supported by the interest of the U.S. Department of Commerce. Levine reviews the development throughout its history of the NACA's roles and responsibilities, neither of which the NACA's authorizing statute and legislative history had clearly defined. He concludes that, through the years from 1926, when the Department of Commerce established its Bureau of Air Commerce, to the mid-1950s, the NACA "played a significant role in the technical development of aviation in the United States. NACA was widely acknowledged in the scientific and technical world as a superb research agency, which made numerous important contributions to the development of airplane design and performance." After discussing the events surrounding the creation of NASA and reviewing the legislative history establishing it, Levine compares and contrasts the creations of the NACA and NASA.

Noor, Ahmed K., Samuel L. Venneri, and Jeremiah F. Creedon. "The First Hundred Years Are the Hardest." In "100 Years of Flight," special issue of *Mechanical Engineering* (January 2003): 30–34. This article describes the work that the NACA and NASA performed to fulfill their role "to face many of the questions raised by flight during the past century, and to contribute innovative answers." For example, the NACA addressed the problems created as airflow in wind tunnels began to approach the speed of sound, causing the tunnels to choke on the shock waves that formed in the compressible fluid. In response to this problem, the NACA positioned a series of slots at critical locations in the throat of the wind tunnel's test section, thereby minimizing measurement errors and "enabling aerodynamic characteristics to be evaluated up to and through the speed of sound." The

NACA's first wind tunnel with a slotted throat aided future research on supercritical wings and winglets. The authors note that both the NACA and NASA "often had to leap past the technology of the day just to design their facilities." NASA's research addressed discrepancies between the atmospheric conditions of wind-tunnel models and full-scale aircraft, determining that lower air temperatures enabled wind tunnels to achieve full-scale Reynolds numbers that measured the relative effects of the inertia and viscosity of the air flowing over the aircraft. The result was the development of the 0.3 Meter Cryogenic Tunnel and the National Transonic Facility at Langley. Both the NACA and NASA have used their facilities to perform studies of airfoils, propellers, and other features of airplanes, and their research has greatly increased the efficiency of flight. The NACA conceived engine enclosures, or cowls, to reduce the aerodynamic resistance of radial-engine aircraft, while maintaining adequate cooling flow and increasing speed; the NACA conducted analytical studies of airfoils; NASA's researchers developed the propulsion-induced-lift concept known as "externally blown flap," which enables reduced runway length; NASA made extensive wind-tunnel studies of a series of airfoils for high-speed flight, enhancing flight efficiency; both the NACA and NASA conducted and sponsored extensive studies on the reduction of jet noise; NASA's research addressed problems associated with wind shear; and NASA's researchers have improved understanding of the wave vortex, which affects air traffic.

Hansen, Frederick D. "System Safety in Early Manned Space Program: A Case Study of NASA and Project Mercury." *Journal of Air Transportation* 10, no. 1 (2005): 104–128. This case study reviews NASA's involvement in efforts to identify best practices to improve system safety. The study includes a section on the NACA's history and its landmark achievements. The author notes that, in the 1920s and 1930s, the NACA concentrated its research on aerodynamics and aerodynamic loads, working closely with the military services in "joint projects that were its contractual lifeblood." During the World War II era, the majority of the NACA's research effort focused on the improvement of current designs or "quick fixes" of military aircraft already in production. In the late 1940s, the NACA, the Army Air Force, and the U.S. Navy conducted research at Edwards Air Force Base that affected the designs of future military aircraft, and by the early 1950s "the entire aviation industry (commercial and military) were profiting from this research."

Temple, L. Parker, III. "X-15B: Pursuit of Early Orbital Human Spaceflight." *Air Power History* 55, no. 1 (Spring 2008): 29–41. This article describes the NACA's work on the lift properties of the rocket-powered X-15 and discusses the role of humans in spaceflight. The NACA's researchers studied high and low lift-to-drag ratios on the X-15, as well as a "triangular planform" to use reentry lift to increase the number of available X-15 landing sites. The X-15 program improved the technology and the knowledge base needed for further spaceflight. Moreover, because of the success of the X-15 program, the NACA and the U.S. military raised the priority of uncrewed space missions. Before the X-series programs, policymakers debated the necessity of uncrewed spaceflight. However, by the time the X-15 program ended, having made 199 flights, "the U.S. was well along the path towards operational space vehicles and human spaceflight."

Starr, Kristen Amanda. "NASA's Hidden Power: NACA/NASA Public Relations and the Cold War, 1945–1967." Ph.D. dissertation, Auburn University, Alabama, 19 December 2008. This dissertation describes how the NACA and NASA presented their work to the public. In the NACA's early years, the committee used its technical reports, technical notes, and its annual aircraft engineering conferences to project the NACA's public image. "The annual conference, held in mid-May, was actually a combined technical meeting and public relations extravaganza," showcasing the NACA's accomplishments to industry and military representatives, as well as to aviation writers. Classified reports replaced these publications during World War II, and as a result, the public was generally unaware of the NACA's accomplishments or of its shift from basic aeronautic research to military development projects necessary to the war effort. In 1945 the NACA created the Office of Public Information (OPI) to clarify its position in the military aviation industry complex, and to address the encroachment of the military and aviation industry on the NACA's research designation. The NACA's OPI also addressed the U.S. Army Air Force's and the aviation industry's criticisms of the NACA, such as the military's complaint that the NACA had failed to develop jet engines during the war. OPI told the U.S. Congress, the aircraft industry, and the military that the NACA intended to conduct research beneficial to the aircraft industry and to the military, after conducting development for military needs during World War II. In addition, OPI gave speeches during the 1950s to aeronautics organizations, aviation writers, and university professors and students, promoting the idea of peace through air power, and extolling the NACA's expertise in advancing the development of technologies, as compared to technology development in Communist countries.

Launius, Roger D. "The NACA Model for Technology Transfer." *Space News*, 11 April, 2012. http://www.spacenews.com/srticle/naca-model-technology-transfer (accessed 18 September 2014). This short article by a former NASA Chief Historian, Roger D. Launius, acknowledges that in 2012 NASA officials discussed "the importance of NASA returning to its roots as a research and development agency dedicated to advancing the basic technology for spaceflight that may then be transferred to the private sector for further development and application. Invoking the NACA model [was] often a part of the discussion." Launius reviewed the methodology underlying the NACA's research projects from the 1920s through World War II, including how the NACA obtained and evaluated research requests from the military, government agencies, and other sources; how the NACA executed its research; and how the NACA disseminated its research findings. He concludes with "two questions that must be asked," but he does not propose a response. "Is this the model NASA should pursue going forward when it comes to research and development of space technologies? Assuming some changes in NASA's approach are appropriate, how might the NACA model of technology transfer be altered for a new age in the 21st century?"

Ferguson, Robert G. *NASA's First A: Aeronautics from 1958 to 2008*. NASA SP-2012-4412. Washington, DC: NASA, 2013. Although this book from the NASA History Series is about aeronautics during the NASA era, the author, Robert G. Ferguson, also discusses the NACA era, because "NASA's aeronautics research did not spring forth anew in 1958 but was a continuation of NACA work under a new name and mission." Ferguson

focuses on the long-term characteristics of the NACA's post-World War II research. During the period immediately following the war, the NACA emphasized high-speed, high-altitude research employing jet and rocket engines. After reviewing the organizational structure and research projects of the Langley, Ames, and Lewis laboratories, and the Wallops Island and High Speed Flight Station test areas, Ferguson argues that the NACA's aeronautics researchers, under the direction of Hugh Dryden, had chosen to take the NACA into space before the establishment of NASA. The NACA had already adopted a resolution stating that "space was part of the NACA's organic mission." In addition, a NACA report on space technology had "laid out the NACA's policy vision that the NACA would form the template and core of a civilian space science agency."

TECHNOLOGY AND RESEARCH

"Proposed Aerological Stations." *Aviation and Aeronautical Engineering* 2, no. 6 (15 April 1917): 268. According to this article, the NACA was encouraging U.S. scientists to develop atmospheric charts of our continent and adjoining waters. Charles D. Walcott, Secretary of the Smithsonian Institution and Chair of the NACA's Executive Committee, urged members of the Aero Club of America to champion the need for atmospheric surveys of North America and its surrounding waters, in order to record and chart atmospheric irregularities. Aviator safety and efficient flying were the goals of this effort.

New York Times. "Heavy Oil Engine Found for Aircraft." 17 April 1923. This article reports the NACA's development of an aircraft engine using heavy fuel oil rather than gasoline. The use of gasoline to fuel aircraft had been the fundamental cause of air accidents involving fire. The NACA planned to report its research on the new engine at an upcoming semiannual meeting of its Advisory Committee, as well as discussing research on a high-speed airplane wing and a device for obtaining data and making tests under actual service conditions.

New York Times. "Report Device Adds to Airplane Power." 10 November 1928. This article announces that the NACA had designed an airplane-engine cowling that supplied as much as 30 percent more horsepower to radial air-cooled engines. The installed cowling was capable of reducing drag so effectively that a 200-horsepower engine that propels an airplane 125 mph without the cowling would be able to propel the same airplane at 166 mph with the cowling, saving 3 gallons of fuel for each hour the airplane flies. NACA Chair Joseph S. Ames proclaimed the cowling the most important contribution to airplane efficiency since World War I. The NACA's researchers had used the propeller-research wind tunnel at Langley Field Laboratory to develop the cowling, which routed air smoothly over the engine and down the fuselage, yet allowed enough cooling air into the radial engine to maintain the proper operating temperature. The cowling would only cost $25 per airplane to install at the factory as standard equipment, but its future benefit was incalculable.

Andrews, Marshall. "Flying and Fliers." *Washington Post*, 10 February 1929. This article describes efforts to reduce air drag created by air-cooled radial engines. Engineers working in secret at the NACA's Langley Field Laboratory had developed the Number

10 cowling, which added 20 mph to a Wasp-engined Curtiss AT-5A and kept its engine cool. Frank Hawks would later use the cowling in his Wasp-engined Vega monoplane to set a transcontinental speed record flying east to west across the United States, at an average speed of 170 mph.

New York Times. "Cowling Effective in 3-Engine Planes." 14 February 1929. This article summarizes a NACA report regarding the application of engine cowling to airplanes with three engines. Applied to tri-engine airplanes, the NACA's cowlings produced a 20 to 25 percent increase in the airplanes' speed and range, with a corresponding savings in fuel. The NACA's cowling also enabled a tri-engine airplane that had lost the power of one of its engines to maintain its airspeed and to remain aloft. The ability of cowled tri-engine airplanes to continue flying with the loss of one engine was an advantage in commercial aviation.

Carmody, Frank J. "Greater Safety and Lower Cost Set as Aviation Goal." *Washington Post*, 22 December 1929. According to this article, the NACA claimed that lowering the costs of aviation and making it safer would help American commercial aviation grow. To improve aviation safety, the NACA was conducting research on low-speed control, load distribution, spinning, and stability. The NACA considered aviation a special form of transportation, not a form of transportation that could replace other forms.

New York Times. "Civil Craft Take Lead." 18 May 1930. This article highlights the NACA's involvement in the development of commercial aircraft. According to this article, NACA Chair Joseph S. Ames had indicated that the Langley Field Laboratory was primarily oriented toward the development of commercial aircraft and only incidentally involved with military aircraft. The Langley facility was developing supercharger and diesel engines for aircraft, in the hope of producing more reliable, more powerful, and safer engines.

New York Times. "Air Pressure in Closed Cabin Planes Affects Instruments, N.A.C.A. Finds." 17 May 1931. This article explains that the NACA's research had prescribed the air-tight sealing of instruments and fittings to prevent the inaccurate instrument readings that result from changes in air pressure at different heights and in various atmospheric conditions. Tests at Langley Field Laboratory using a Fairchild monoplane had demonstrated that failure to seal instruments and fittings properly could cause instruments to read elevation and air speed incorrectly.

New York Times. "Slots and Flaps Bring Better Lift, Greater Safety, N.A.C.A. Tests Show." 31 January 1932. This short article cites the NACA's research of tailless airplanes. Tail sections, which include the rudder and stabilizer, improve an airplane's lateral stability during takeoff, flight, and landing. However, the introduction of wing slots and flaps provided sufficient lateral stability to make the tail assembly unnecessary. The NACA's research indicated that using flaps along the wing's trailing edge and slots at the wing's leading edge improved lift, increased speed range, increased angle of landing glide, and decreased landing speed.

Baltimore Sun. "Lightning Held 'Slight' Hazard to Planes in Air: National Advisory Committee for Aeronautics Reveals Results of Investigation." 10 March 1934. This article reports the results of a NACA committee's investigation of the dangers of lightning strikes to airplanes. The committee found that lightning poses a "very slight" hazard to aircraft in flight. The U.S. Navy had requested the investigation after losing dirigibles during electrical storms—Shenandoah in 1923 and Akron in 1933. NACA Chair Joseph S. Ames appointed the NACA committee early in 1934.

New York Times. "Combustion Is Pictured." 5 August 1934. This article describes the techniques that the NACA's Langley Field Laboratory used to observe combustion-chamber detonation and the fuel-injection process. To determine how variables in fuel and air delivery affect the rate of combustion, engineers had created an engine with windows in the combustion chamber. They had also created cameras capable of taking 25 pictures at 8,000 frames per second. Engineers reviewed these pictures to understand the variation in fuel delivered to different cylinders in the same engine.

Cleveland, Reginald M. "Contact." *New York Times*, 7 April 1935. This short article reports the U.S. Navy's praise for the work of the NACA. The Navy claimed that the NACA's scientific research was responsible for making American airplanes equal or superior to those that other nations had developed. For example, the NACA researchers had used a 7-foot-by-10-foot wind tunnel to learn how to improve pilots' vision during poor weather.

U.S. Congress. House of Representatives. Committee on Military Affairs. *Hearings on Development of* the *Autogiro and Rotary-Winged Aircraft*. 75th Cong., 3rd sess., 26 and 27 April 1938. These hearings include the testimony of NACA Director of Aeronautical Research G. W. Lewis in support of legislation authorizing the appropriation of funds for the development of the autogiro. Lewis stated that he "believes in the future possibilities of the rotating-wing type of aircraft." He pointed out that departments like the Army and Navy, which foster the development of this type of aircraft, "must necessarily take the funds from the development of aircraft of the non-rotating–wing type." Lewis discussed work underway at Langley Field, which operated a "full scale wind tunnel large enough to place a complete autogiro in the wind tunnel under circumstances such as to measure the thrust, lift, drag, and pitching movement, and the control." He noted that the research program at Langley studied all types of rotative wings, the autogiro, the gyroplane, and the helicopter. Lewis included in his testimony the text of an April 1938 outline of the NACA's autogiro research program.

Washington Post. "Device Found To Warn Pilot of Plane 'Stall': Big Step Toward Safety." 17 October 1938. This article describes a stall device that the NACA engineers at Langley Field Laboratory created to warn pilots when an airplane is slowing so considerably that its airspeed can no longer sustain lift under its wing. When the device detected a stall, it turned on an instrument light, sounded a horn, or vibrated the pilot's control stick.

New York Times. "Progress in the Air." 10 January 1939. This article announces the NACA's most recent annual report, which issued a warning about the future of U.S. aeronautics. The NACA's annual report predicted that other nations would overtake the United States

in fundamental aeronautical research unless the United States expanded its research facilities. For example, the United States must undertake additional scientific research in aeronautics to meet U.S. military requirements to produce aircraft that can fly between 300 and 400 mph. In addition, the NACA reported that the more efficient aircraft would dominate international air transport.

Baltimore Sun. "500 M.P.H. Speed for Planes Reported Near Realization." 3 May 1939. This article reports that the NACA had claimed that streamlining airplane wings and fuselages would help airplanes fly faster than 500 mph. Although shock waves slow the speed of airplanes as they approach 500 mph and again as they near 710 mph, which is the speed of sound, the NACA's engineers believed that changes to the structural design of aircraft could overcome the effects of shock waves on airplanes approaching these speeds. The article also notes that the NACA had recently invited airplane designers and manufacturers to its Langley Field Laboratory, to view a dozen wind tunnels that simulated flight conditions.

Baltimore Sun. "Dr. Ames Declares U.S. Leads in Aeronautical Knowledge." 15 October 1939. This article reports the opinion of former NACA Chair Joseph S. Ames regarding the United States' world leadership in the field of aeronautical science. Ames said that the United States would maintain its lead because of the large scale of its aeronautical research and the focus of its research on basic scientific problems. Ames praised those who had led the NACA's early efforts to organize and conduct aeronautical research.

Chicago Daily Tribune. "Developing Speedy Airplanes: Build Superengine." 14 November 1939. This short article reports that, in experiments at the NACA's Langley Field Laboratory on how to remove heat from cooling fins, engineers developed an airplane equipped with a new, secret type of wing, capable of flying at a speed of 500 mph. A new four or six-blade propeller, replacing the two and three-blade propellers, also contributed to the airplane's speed. The article features pictures of the building, showing the wind tunnel and a model airplane undergoing experiments within the tunnel.

McBee, Avery. "Giant NACA Laboratories Keep U.S. Planes Ahead." *Baltimore Sun*, 19 November 1939. This article summarizes some of the NACA's capabilities at the close of 1939. The NACA's engineers had increased engine horsepower by 30 percent by lengthening engine-cooling fins and placing them closer together. The NACA engineers had also designed wing flaps and slots that cut air resistance and had increased the speed of aircraft. The article concludes with a list of the NACA committee members, including Charles A. Lindbergh and Orville Wright.

Andrews, Marshall. "American Engineers Search for Plane Improvements in Nation's Foremost Aerodynamics Laboratory." *Washington Post*, 5 January 1941. In the first of a two-part article about the NACA's experiments at Langley Field Laboratory, the author reports that the NACA's Langley facility was spending more time working to improve airplanes for the use of the American armed forces than on basic scientific research. Researchers at Langley Field were attempting to create the airplane of the future for the U.S. Army. Research topics at Langley included experiments with supercharger production to

increase aircraft horsepower and the removal of extraneous wires and struts to create improved airflow over airplanes. In addition, the NACA engineers were using cameras to detect air shock waves that develop as airplanes approach the speed of 500 mph.

Andrews, Marshall. "N.A.C.A. Engineers at Langley Field Laboratory Overlook Nothing in Effort To Perfect American Aviation." *Washington Post*, 12 January 1941. In the second of a two-part article about the NACA's experiments at Langley Field Laboratory, the author describes how the NACA's engineers were using Langley's wind tunnels to measure weight and pressure and to conduct airflow experiments. The NACA had developed its own cameras, which took 40,000 pictures per second, to photograph engine-combustion experiments. The NACA had begun its research in 1917 with the U.S. Army's donation of a Curtiss JN-4D "Jenny." This article includes a picture of a propeller used to direct air in one of the NACA's wind tunnels at Langley Field. The propeller's giant blades were made of laminated spruce.

McWethy, John A. "Tomorrow's Plane Is Being Fashioned, Bit by Bit, from Research on U.S. Fighting Craft." *Wall Street Journal*, 31 July 1943. The article explains that the NACA was using its three test facilities to solve urgent flying problems for the U.S. military and to create the airplane of the future. Before World War II, the NACA had worked with aircraft manufacturers to improve aeronautical performance, but once the war had begun, the NACA was devoting all of its research to the armed services. However, manufacturers were permitted to ask one of the U.S. armed services to refer an issue to the NACA for study. The NACA's work to improve World War II aircraft would inform the design of post-war aircraft. The NACA maintained a large technical library at the Office of Aeronautical Intelligence in Washington, DC.

Wall Street Journal. "Device Protects Planes from Formation of Ice: NACA Invention Uses Exhaust Gases To Keep Leading Edges at 60 Degree Temperature." 2 August 1943. This short article announces that Consolidated Vultee Aircraft Corporation's and the NACA's joint invention of a device that uses an engine's exhaust gases to heat wings and tail edges. The invention routed heated air from the exchangers in the engine's exhaust pipes to the leading edges of the airplane's wings and tail surfaces, thereby preventing the formation of ice on those surfaces. As soon as the aircraft's engines started, built-up ice and snow began to melt from the leading-edge surfaces of the wings and tail.

Christian Science Monitor. "Waste Engine Heat Harnessed in New Setup to De-Ice Planes." 10 February 1945. This short article announces the development of a mechanism that used an engine's exhaust heat to deice the airplane's parts. The engine's heated air circulated to the aircraft's control surfaces, such as the wing edge and the tail surfaces, to prevent ice from forming and negatively impacting airplane control. In addition, the engine's hot air was pumped between the double-pane cockpit windshield to prevent ice from forming on the outer pane. Army airplanes were already using the new system, and the Navy planned to employ the system in its airplanes. The NACA's Aircraft Engine Research Laboratory in Cleveland, Ohio, had conducted the research on using waste engine heat to deice airplane parts.

Sturdy, Frank. "500 M.P.H. Wind Roars thru Jet Tunnel Testing." *Chicago Daily Tribune*, 24 June 1945. This article describes the NACA's efforts to verify the results of wind-tunnel tests using actual flight data. The NACA had compared test data for high-speed performance in a wind tunnel to actual flight data. The NACA used a 50,000-horsepower wind tunnel that produced wind speeds up to 500 mph. Researchers could control humidity, pressure, and temperature inside the 20-foot-diameter wind tunnel. For example, they could refrigerate the tunnel to -48ºF to simulate conditions at high altitude. The NACA compared wing-load-stress measurements from wind-tunnel tests and from actual flights to verify simulated flight results. As flight speeds approach the speed of sound, the flow of air over a wing changes, drag increases, and surfaces of the airplane's controls do not respond to pilot inputs. Comparing the wind-tunnel test results with actual flight-performance results would help the NACA's engineers overcome such problems. The article also discusses petroleum-fuel research and states the speed of the turbojet-powered P-80 Shooting Star.

Brunn, Robert R. "Moon Ahoy?—Supersonic Plane Hurtles Through Paces in Aero Lab." *Christian Science Monitor*, 13 August 1946. This article highlights experiments at the NACA's Ames Laboratory aimed at overcoming the effects of shock waves on airplanes as they near the speed of 750 mph. Of the eight wind tunnels at Ames Laboratory, two measured 2 feet by 3 feet and were capable of reaching supersonic speeds as high as 2,500 mph. The Ames facility also had a one-of-a-kind wind tunnel that engineers could pressurize to create low turbulence within the tunnel, thereby improving transonic stability and control testing.

Science News-Letter. "NACA and Army Design XS-1." 17 August 1946. The article reports that a Bell Aircraft-Army XS-1 experimental-research aircraft would attempt to fly faster than the speed of sound. The NACA had developed the high-speed design principles used in the XS-1, using a scale-size model to conduct wind-tunnel tests at speeds of up to 96 percent of the speed of sound. The XS-1's top speed would depend upon how well the controls reacted as the rocket-powered aircraft approached the speed of sound.

"NACA Scientists Reveal Torrid Zone in Upper Atmosphere." *Journal of the American Rocket Society*, no. 69 (March 1947): 1–4. This article reports the results of a NACA study that revealed the existence of perpetually torrid layers of air in the otherwise cold upper atmosphere of Earth. The study found that the 170° hot zone extended from an altitude of approximately 30 miles (48.3 kilometers) to an altitude of more than 40 miles (64.4 kilometers). A special NACA committee, headed by Harry Wexler of the U.S. Weather Bureau, had conducted research since April 1946 to gather new information on the outer reaches of Earth's air envelope. According to the author of this article, "establishment of a 'standard' atmosphere is a necessary prerequisite to the development of new aircraft and guided missiles designed for upper atmosphere travel. These new findings will make necessary new design and construction techniques to permit aircraft operations in these torrid zones."

New York Times. "First 'Silent' Plane Shown in Virginia." 21 May 1947. This article describes the demonstration of the first "silent" airplane, which the NACA's engineers had

developed to address the issue of excessive airplane noise. The airplane had a five-bladed propeller that reduced noise pressure by 90 percent, resulting in a noise level at 300 feet comparable to that of a glider. The NACA reported that the airplane was the first "in which all noise-silencing methods had been fully applied."

Washington Post. "1700 mph Wind Tunnel at Langley." 22 August 1948. This short article describes the preparations at the NACA's Langley Field Laboratory for the construction of a 1,700-mph wind tunnel featuring a test section measuring 4 square feet. The supersonic tunnel at Ames Laboratory was currently the NACA's largest supersonic wind tunnel, with a 3-square-foot test section that could test a 6-inch model. The first of three new tunnels that the NACA is building, Langley's 1,700-mph wind tunnel would be the smallest and the fastest of the three. It would have a 1,100-blade compressor, instruments that recorded speed and pressure, and observation windows.

Hurd, Charles. "NACA Stepping Up Its Sonic Research." *New York Times*, 5 April 1949. This article summarizes a report that the NACA submitted to the U.S. Congress explaining the NACA's plan to accelerate research on supersonic flight. The NACA was taking this step because it anticipated that "improved models of present military planes 'will encounter flight conditions for which basic design information is still lacking'." According to NACA Chair Jerome C. Hunsaker, the NACA's immediate objective was to "solve, as quickly as possible, the most pressing problems attendant on high-speed flight." Hunsaker also noted that flights of the Air Force's X-1 and the Navy's D-558 had enabled the NACA to conclude that it was possible to build aircraft that pilots could safely control at transonic flight speeds.

U.S. Congress. House of Representatives. Committee on Interstate and Foreign Commerce. Subcommittee [unnamed]. *Hearings on Development of Improved-Type Aircraft*. 81st Cong., 2nd sess., 25 July, 7 August, and 17 August 1950. These hearings include the testimony of NACA Associate Director for Research J. W. Crowley in support of legislation to assist the development of improved commercial-transport aircraft. In the NACA's opinion, this bill provided "stimulus for the aircraft industry to proceed with required prototype developments while maintaining the private initiative of the industry," and "a means for conducting much needed research at an accelerated pace."

New York Times. "N.A.C.A. at Forty." 13 May 1955. This short article congratulates the NACA for forty years of service as a "bulwark" to national defense and "spearhead of peacetime progress." The NACA's committee members, who served without pay, had established priorities and planned research programs for 7,000 civilian personnel. Without the NACA's research and development in the field of aerodynamic design, the nation's defense and commercial aircraft would have lagged behind those of other countries. The NACA's technical guidance had helped create U.S. aircraft that fly at speeds greater than the speed of sound.

Hartford Courant. "NACA Aims at Nuclear Plane Power: Research To Develop Atomic Engine Under Way at Laboratory." 2 June 1954. The article describes the research into atomic engines that the NACA's engineers were conducting at the Lewis Flight Propulsion

Laboratory in Cleveland, Ohio. Within 25 years, the researchers expected to build an engine that used fission to propel an airplane. Fission of one pound of uranium produces enough heat to propel an airplane nonstop around the world. In addition, the article reported the first public demonstration of reverse thrust in a jet airplane, explained how airplane shells overheat at extreme speeds, and described a new fuel called propylene oxide that had fuel efficiency at high speeds that was more than twice the efficiency of ordinary jet fuel.

Cooke, Richard P. "Reverse Thrust Device Tested To Stop Jets from Skidding Off Icy Runways." *Wall Street Journal*, 4 June 1954. This article describes the NACA's experiments using the reverse thrust of jet engines to slow down airplanes during landing. When an airplane lands on an icy runway, its brakes cannot slow it sufficiently to stop the craft before the runway ends. However, using the engine's reverse thrust can help the airplane come to a halt. Opening the engine's vanes, which resemble clamshells, allows exhaust gases to thrust forward, slowing the airplane as it travels down the runway.

New York Times. "New Jet Is Used in Altitude Study." 7 May 1956. This article announces the NACA's reliance on U-2 ultra-high-altitude-aircraft flights to capture data. The NACA was acquiring high-altitude-weather-condition information from U-2 flights. The U.S. Air Force utility plane gathered cosmic ray, ozone, water vapor, and wind data that the NACA could not acquire using its altitude pressure chamber. The Lockheed U-2 did not exceed the speed of sound; it routinely flew at 50,000 feet and could linger for more than an hour at that altitude.

Witkin, Richard. "Aviation: Jet Fields." *New York Times*. 28 October 1956. This article describes the use of the exhaust gases of jet engines to shorten takeoff and landing distances. The NACA's engineers used vanes to route hot exhaust gases upward through "a gap between the back of the wing and the front of the wing flap," increasing airflow over the top of the wing flap. The increased airflow increased the airplane's lift, shortening the length of takeoffs and landings. Fitted with the NACA's system, a 300,000-pound airplane, such as the Boeing 707, would be able to take off in 4,500 feet, instead of the 8,500 feet previously required for takeoff, and to land in 3,700 feet, instead of the 8,000 feet previously required.

Witkin, Richard. "U.S. Rocket Plane Has Blunt Design." *New York Times*. 3 February 1958. This article describes the X-15 experimental rocket plane, a joint project of the NACA, the U.S. Air Force, and the U.S. Navy. The airplane featured a blunt and bulging shape that enabled the X-15 to overcome high-velocity shock waves and heat. Triangular bulges running the length of the fuselage minimized the shock waves that occur at the juncture of the wing and fuselage and slowed the airplane as its speed approached the speed of sound. The airplane would travel faster than 3,600 mph and would fly as high as 100 miles above Earth. During initial testing, a B-52 bomber would release the airplane at 40,000 to 50,000 feet. North American Aviation had built the X-15, and Reaction Motors had built the rocket engine.

Becker, John V. *The High-Speed Frontier: Case Histories of Four NACA Programs, 1920–1950*. NASA SP-445. Washington, DC: NASA, 1980. The author, an NACA engineer, insightfully looks at the high-speed airfoil program; transonic wind-tunnel development; high-speed propeller program; and high-speed cowlings, air inlets and outlets, and internal flow systems.

Vincenti, Walter G. "Engineering Theory in the Making: Aerodynamic Calculation 'Breaks the Sound Barrier'," *Technology and Culture* 38, no. 4 (October 1997): 819–851. This article describes the NACA's work atmosphere. The author of the article, formerly an engineer at Ames Aeronautical Laboratory, claims that the NACA's engineers conducted the three phases of modern engineering research (theory, experiment, and trial) side by side at the NACA's laboratories, sometimes with the same group conducting more than one of the phases simultaneously. The NACA's atmosphere was conducive to collaboration. Lunch groups, ride-sharing groups, and committee members shared information with one another, using these interactions to mutual advantage. In addition, management gave successful engineers latitude and time to pursue their own research. The author points out that the NACA's management consisted of researchers who understood the importance of providing sufficient time to study a problem thoroughly.

Hamady, Theodore M. "Destined To Fail: The Nieuport 28 Wing." *Air Power History* 46, no. 4 (Winter 1999): 6–19. This article describes the successes and failures of the Nieuport 28C-1, Boeing MB-3, and Curtiss Orenco D-1, fast-pursuit fighter airplanes in use during the early 1900s. After World War I, the NACA's Langley Field Laboratory had conducted research to determine the distribution of load over the wings of a high-speed airplane under all conditions of flight. This research had measured, for the first time, pressures across the entire span and chord of the wing. The NACA's Executive Committee Chair Joseph S. Ames had presented the preliminary findings of this research to the aeronautical community in 1923. He noted that the results of the NACA's pressure-distribution tests would be of great use to airplane designers, as would the results of tests conducted at Langley's new VDT. The author quotes the conclusion of a work on the history of aerodynamics, which stated that the experimental data that the NACA had obtained using Langley's VDT "made the United States the undisputed leader in applied aerodynamics" for 15 years beyond the 1922 debut of the wind tunnel.

Hamrick, Joseph T. "A Review of the History of the National Advisory Committee for Aeronautics Centrifugal Compressor Program and Arrival at Current Computational Design Procedures." *Journal of Fluids Engineering* 127, no. 1 (January 2005): 94–97. This article describes the work that the Centrifugal Compressor Section of the NACA's Compressor and Turbine Division performed during and after World War II. The Centrifugal Compressor Section designed, built, and tested three compressor impellers during that period. Earlier experiments had reached inconsistent conclusions regarding the basic design of a centrifugal impeller. However, investigations conducted at the Cleveland Laboratory between 1948 and 1955 led to the development of a procedure for a quasi-three-dimensional design, which clarified the conclusions of previous experiments. This article also reviews research efforts leading to recent developments in procedures for computational design.

Baucom, Donald R. "Wakes of War: Contrails and the Rise of Air Power, 1918–1945; Part I—Early Sightings and Preliminary Explanations, 1918–1938." *Air Power History* 54, no. 2 (Summer 2007): 16–31. This article discusses a report that the NACA's engineers wrote to help explain the vortices that airplanes produce during flight. The engineers reported the possibility of using contrail vortices to study the airflow of objects in the wind tunnel. Contrails were mostly unknown until the beginning of World War II, when military airplanes began flying at altitudes above 25,000 feet, in atmospheric conditions more likely to produce contrails than conditions at lower altitudes.

Polmar, Norman. "Historic Aircraft." *Naval History*, February 2008. This article describes the team effort of the NACA, the U.S. Army, and the U.S. Navy to research aeronautical issues arising at speeds approaching Mach 1.2, the speed of sound. The Douglas Aircraft Company developed the D-558 for these test flights. A U.S. Navy test pilot flew the D-558 to 640 mph on 20 August 1947. NACA test pilot Howard C. Lilly crashed and died on takeoff on 3 May 1948, the first NACA test pilot killed in the line of duty. NACA pilot Scott Crossfield reached Mach 2.005 (1,291 mph) while putting a later version of the airplane—the D-558-2—into a dive on 20 November 1950. Crossfield was the first pilot to exceed Mach 2.

Dicht, Burton. "Shuttle Diplomacy." *Mechanical Engineering* 133, no. 7 (July 2011): 46–52. This article describes how NASA later used the NACA's research in the design of the Space Shuttle. In 1952 a NACA engineer had found that high reentry angles created a shock wave that deflects heat away from the aircraft. His theory was dubbed the "blunt body." Therefore, the NACA created the X-15, an experimental aircraft designed to conduct hypersonic test flights, with a blunt body shape that would create a shock wave to deflect heat away from the aircraft and to prevent the craft from overheating. The X-15 successfully reentered Earth's atmosphere, traveling at speeds from hypersonic to transonic to subsonic, without burning up. NASA engineers later copied the NACA's X-15, using a blunt shape on the Space Shuttle to lower the craft's surface temperatures during reentry.

Reade, David. "U-2 Spy Planes: What You Didn't Know About Them!" *Air Power History* 58, no. 3 (Fall 2011): 6–15. This article discusses the NACA's original announcement of the functions of the United States' new U-2 airplane. On 7 May 1956 NACA Director Hugh L. Dryden announced the existence of the U-2, claiming that it was a high-altitude atmospheric and meteorological research plane. According to this article, Dryden's announcement was a cover story intended to disguise the U-2's actual function, which was to engage in covert operations. Although the U-2 did conduct atmospheric and meteorological research, the United States also used the aircraft to detect and monitor the Soviet Union's development and testing of nuclear weapons. Between 1956 and 1960, the United States conducted more than 200 U-2 flights "under the auspices of the NACA/NASA weather research 'cover' missions.

BACK COVER IMAGE:

Image no. L-42612

First meeting of the NACA in 1915 — Description: The first meeting of the National Advisory Committee for Aeronautics (NACA) in the Office of the Secretary of War, 23 April 1915. Brig. Gen. George P. Scriven was elected as the temporary Chairman of the NACA, and Dr. Charles D. Walcott (not pictured), Secretary of the Smithsonian, was elected Chairman of the NACA Executive Committee.

After the Wright Brothers' historic first flight in 1903, the United States began to fall behind in aeronautical research. With the beginning of World War I, the nation realized it needed a center for aeronautical research as a means of catching up technologically with Europe.

On 3 March 1915, the legislation creating the NACA passed and the NACA was born. For 43 years, the NACA worked to advance aviation research until it was eventually absorbed into the new space agency, the National Aeronautics Space Administration, in 1958. Seated from left to right: Dr. William Durand, Stanford University, California. Dr. S. W. Stratton, Director, Bureau of Standards. Brig. Gen. George P. Scriven, Chief Signal Officer, War Dept. Dr. C. F. Marvin, Chief, United States Weather Bureau. Dr. Michael I. Pupin, Columbia University, New York. Standing: Holden C. Richardson, Naval Instructor. Dr. John F. Hayford, Northwestern University, Illinois. Capt. Mark L. Bristol, Director of Naval Aeronautics. Lt. Col. Samuel Reber, Signal Corps. Charge, Aviation Section. Also present at the first meeting: Dr. Joseph S. Ames, Johns Hopkins University, Maryland. Hon. B. R. Newton, Asst. Secretary of Treasury.

. . . 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 . . .

ACT OF CONGRESS, APPROVED MARCH 3, 1915

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