National Aeronautics and Space Administration

THE ARMSTRONG X-PRESS

Volume 57 Number 1 April 2015










NACA NASA 1915 - 2015

100 years

Foundation built by the NACA for NASA to reach for the moon and beyond

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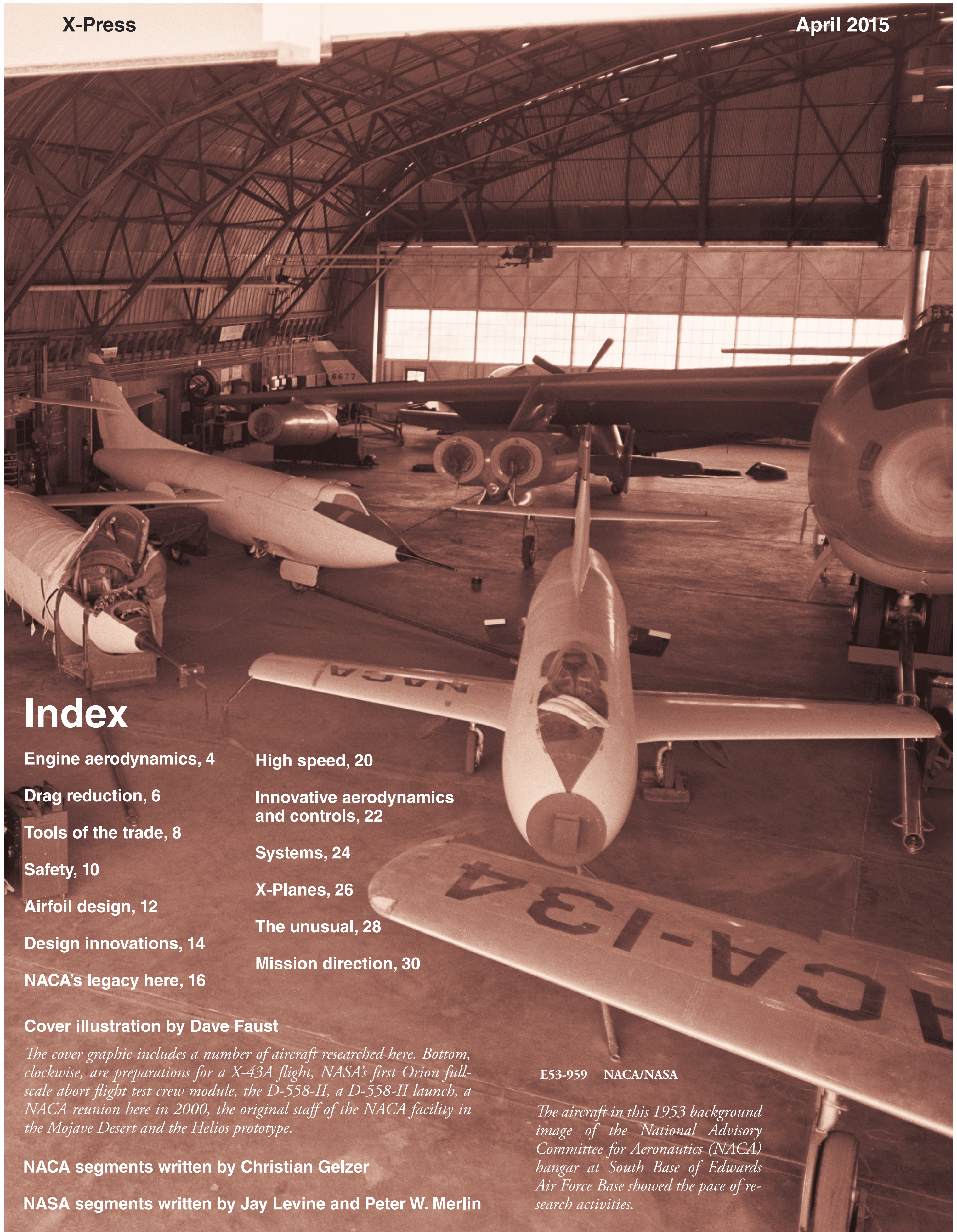

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Cover illustration by Dave Faust

The cover graphic includes a number of aircraft researched here. Bottom, clockwise, are preparations for a X-43A flight, NASA's first Orion full-scale abort flight test crew module, the D-558-II, a D-558-II launch, a NACA reunion here in 2000, the original staff of the NACA facility in the Mojave Desert and the Helios prototype.

NACA segments written by Christian Gelzer

NASA segments written by Jay Levine and Peter W. Merlin

E53-959 NACA/NASA

The aircraft in this 1953 background image of the National Advisory Committee for Aeronautics (NACA) hangar at South Base of Edwards Air Force Base showed the pace of research activities.

100 years

NACA breakthroughs led to NASA's revolutionary accomplishments

The National Advisory Committee for Aeronautics, or NACA, was established in March 1915 as a federal agency to "direct and conduct research and experimentation in aeronautics … to their practical solution." Its creation reflected the nation's waning aeronautical influence in the world, something made especially clear by World War I, which began in 1914: it frustrated many to see the land of the Wrights lose its leadership role.

The NACA (the individual letters are pronounced, unlike its successor agency's acronym) began with one center in 1917, the Langley Memorial Aeronautical Laboratory in Hampton, Virginia. To this was added the Ames Research Center in Sunnyvale, California, in 1940, and the Aircraft Engine Research Center in Cleveland in 1941 (which soon became the Lewis Research Center and today is the NASA Glenn Research Center). In 1945 Langley began operating a small facility on the Atlantic coast known as the Pilotless Aircraft Research Station on Wallops Island, Virginia, and another facility, referred to as the Muroc Unit, California, in 1946. The Muroc Unit eventually became independent and is now called the NASA Armstrong Flight Research Center. All but Wallops and Muroc were created as wartime centers and not expected to last beyond hostilities.

With inspired engineers, a small fleet of aircraft and a growing collection of unique wind tunnels, the NACA developed a reputation for extraordinary research, the results of which were usually widely distributed. That research had an extraordinary impact on the nation's – and the world's – aeronautical development. The results manifested themselves in many ways: much greater flight safety, jumps in airliner efficiency and reliability, higher aircraft speeds, and ever better design tools, to list but a few.

Beyond the aeronautical results, the NACA developed a reputation as a model federal agency, celebrated for its effectiveness. Vannevar Bush, vice president of the Massachusetts Institute of Technology and dean of MIT's school of engineering, also was a science advisor to U.S. presidents and the director of the Office of Scientific Research and Development during World War II. Bush was so impressed with the agency's effectiveness that he patterned the National Defense Research Council directly on the NACA and he sought to do so with the National Science Foundation.

The NACA had many firsts during its existence, only some of which were recognized by awards. From the beginning the committee studied compressibility issues on propeller tips, putting the NACA in the forefront of the subject for decades. Not surprisingly, in 1934 its researchers produced the first visual evidence of shock patterns on a wing at "critical [Mach] speed" using schlieren photography. Also in its first decade the agency became a leader in aviation safety and accident investigation, and some of its engineers went on to develop a spin and stall-proof experimental aircraft in an attempt to demonstrate the potential to industry.

Between 1915 and 1958 the NACA published more than 16,000 reports for public use regarding aeronautical design, research, safety, and development. In that time it won outright or shared in five Collier Trophies, an award established in 1911 and presented "for the greatest achievement in aeronautics or astronautics in America, with respect to improving the performance, efficiency and safety of air or space vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year."

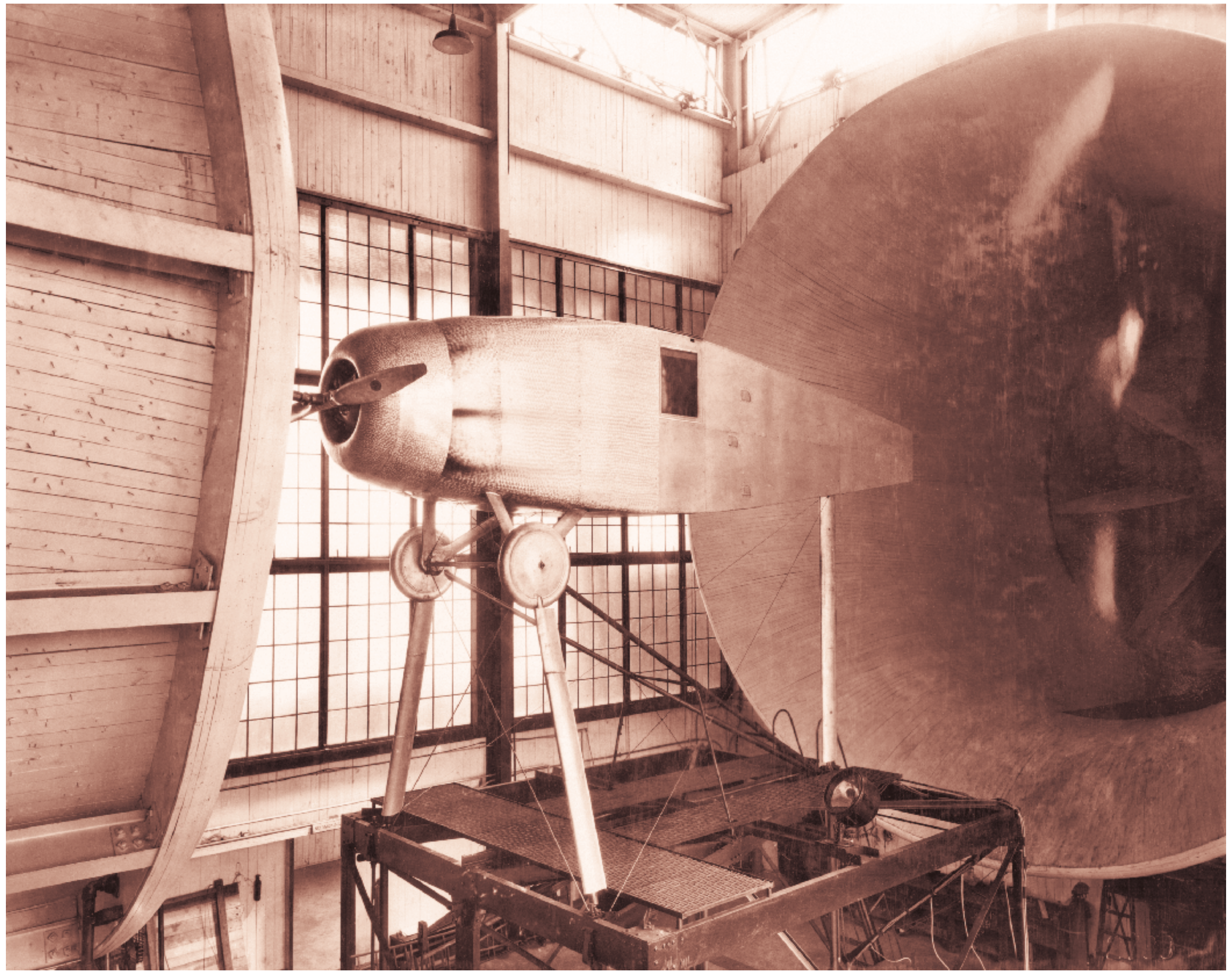
In 1958, and in direct response to another international event – the Soviet launch of Sputnik I and II – President Dwight D. Eisenhower reorganized the NACA and renamed it the National Aeronautics and Space Administration, or NASA. Despite a focus on space, the agency has continued its aeronautical work, yielding benefits to the nation and the world.

The benefits have included fundamental research on swept wings so critical to high-speed flight, solving deadly problems resulting from the combination of new aircraft planforms and jet engines, exploring variable incidence wings and conducting the first human piloted hypersonic flight. Also included were exploring entirely new re-entry shapes to change access to space, developing the foundation for modern remotely piloted aircraft and introducing entirely new flight control methods and testing.

NASA also was responsible for evaluating new safety systems for passenger travel and military aircraft, developing the very first self-repairing flight control systems in aircraft, developing and bringing to practical use new, lightweight instrumentation systems and much more. Since NASA's founding in 1958 it has won outright or shared in 12 Collier Trophies.

One hundred years and counting the NACA's legacy is alive and well: NASA is with you when you fly.

Christian Gelzer
Chief Historian at NASA Armstrong Flight Research Center
Jacobs Technology



GPN-2000-001387 NACA/NASA

Drag was a major problem for aircraft and the Langley Memorial Aeronautical Laboratory's (now NASA Langley Research Center in Hampton, Virginia) early research was focused on reducing it. One method was to place a cowling or covering over the engine cylinder heads, much like the hood over the engine of a car. In September 1928, tests of Cowling No. 10 in the Propeller Research Tunnel showed a dramatic reduction in drag.

Category 1: Engine aerodynamics

Cowlings improved engine cooling, reduced drag

Using the large Subsonic Wind Tunnel at the Langley Memorial Aeronautical Laboratory (now NASA Langley Research Center in Hampton, Virginia), engineer Fred Weick explored the relationship between engine cowlings and drag. To this point theory held that the best way to cool an engine was to put the cylinders, if not the entire motor, in the airflow.

His research showed that a NACA-designed cowling would both improve engine cooling and reduce drag. The U.S. Navy approached the NACA in 1926 asking it to explore a circular cowling for radial engines. By 1928 engineers showed convincing results using the full scale Propeller Research Tunnel. Charles Lindbergh's Spirit of St. Louis, which he flew across the Atlantic in 1927, didn't have a cowled engine that would have given him greater range, better speed and a cooler engine.

Cowled radial engines soon appeared on aircraft, improving efficiency, and the concept was a material factor in World War II military aircraft air-cooled engines. For this work the NACA received the Collier Trophy in 1929 "for development of cowling for radial air-cooled engines," the agency's first such award.

The Boeing Company / Bob Ferguson

NASA partnered with industry for these tests of chevron nozzles on a specially modified General Electric engine mounted on a Boeing 777. Chevrons are the serrated edges on the back of the nacelle and the engine exhaust nozzle to greatly reduce the sound of jet blast from the rear of the engine.

Category 1: Engine aerodynamics

Chevrons lead to quieter engines

Aerospace chevrons contribute to significant engine noise reduction of large commercial aircraft.

Part of a NASA Glenn Research Center, Cleveland, and industry partnership to quiet future jetliners, the aerodynamic devices have a serrated, or saw-tooth, pattern. They are used on jet engine cowlings on the back of the nacelle, or fan housings, and where engine exhaust exits.

Chevrons work by mixing hot air from the engine core with cooler air blowing through the engine fan. The shaped edges of the aerodynamic devices smooth the mixing air, which reduces turbulence that creates noise. Research showed perceived jet noise levels were reduced by about half using chevrons.

A number of commercial aircraft began using chevrons less than 10 years after the validation of their benefits. A few large jetliners also use them including the Boeing 787. The aircraft has chevrons on the nacelles. The Boeing 747-8 also features the devices on the nacelles and inner engine core nozzles.

GPN-2000-001393 NACA/NASA

The Langley flight crew installs an experimental low-drag cowling on the Fokker Trimotor in 1929. Such cowlings increased fuel efficiency and overall performance. This image shows the aircraft prior to the relocation of the engines that resulted in the big gains in performance.

Category 2: Drag reduction

Engine location reduced drag

An offshoot of the NACA engine cowling research was the discovery that placing aircraft engines on the wing's leading edge improved efficiency. The practice had been to hang the engines under the wings. Testing on a Fokker Tri-Motor with NACA cowlings found the cowlings made no difference until the engines were later relocated – then everything changed.

Not only did this improve efficiency and speed, it also facilitated the relocation of wings from above the fuselage to below it, resulting to shorter landing gear and less drag, redefining the airline – even the entire aircraft – industry. Additionally, NACA research showed that fixed landing gear accounted for nearly 40 percent of total drag of a typical aircraft in the early 1930s, leading to major fairing work that was adopted by industry and development of retractable landing gear.

EC96-43548-10 NASA/Jim Ross

A modified F-16XL No. 2 conducted laminar flow testing. The aircraft flew with a modified titanium wing glove that contained more than 10 million holes and has a suction system attached to the lower surface. During flight the suction systems pulls a small part of the boundary layer of air through the glove's porous surface to create laminar (or smooth) airflow.

Category 2: Drag reduction

Laminar flow control improves efficiency

Smooth, or laminar, airflow at a wing's leading edge gradually gives way to more turbulent flow toward the trailing edge, which causes excess drag. An ideal airfoil would have laminar airflow across the entire surface of the wing, thus improving both aerodynamic efficiency and fuel consumption.

Since the 1960s, researchers at NASA Dryden (now Armstrong) and NASA Langley Research Center in Hampton, Virginia, have collaborated on a variety of projects to control laminar airflow using both active and passive systems. Active test sections contain tiny holes or slots through which most of the turbulent layer of air is siphoned off by an internal suction system built into the wing.

Test bed aircraft for these efforts have included the X-21, JetStar, F-14A and F-16XL, as well as the Pegasus winged rocket and a small experimental airfoil carried beneath an F-15B on a ventral fixture. Testing at actual flight conditions enables engineers to capture data that will allow more precise refinement of airfoil designs for improved laminar flow.

GPN-2000-001248 NACA/NASA

A P-51 Mustang was researched in the Langley Full Scale Tunnel on Sept. 23, 1945.

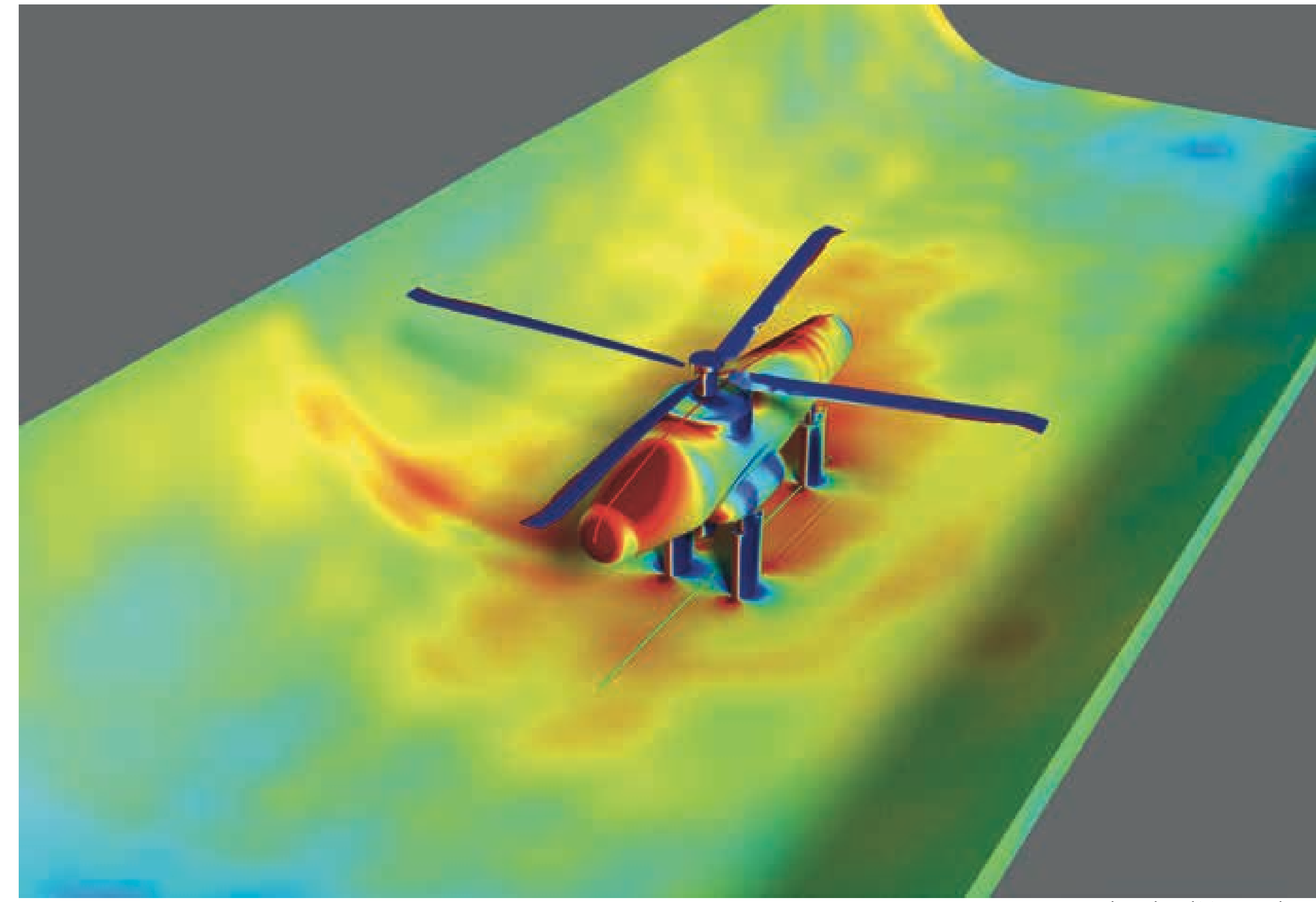
Category 3: Tools of the trade

NACA wind tunnels revolutionized modeling

The NACA provided the first major wind tunnels to the U.S. government. In 1923 the NACA began operating the world's first Variable Density Tunnel, capable of accurately modeling flight using scaled models because pressure in the wind tunnel could be varied to match Reynolds numbers.

In 1934 the NACA had the Langley Full Scale Tunnel with the world's largest wind tunnel section. At 30 by 60 feet it allowed an entire aircraft to be tested, not just components. The NACA also operated the Propeller Research Tunnel, which was so critical to engine cowling studies.

Another wind tunnel to appear over the decades included the first transonic wind tunnel (1941), which eventually became one of the world's first slotted-throat wind tunnels. It was essential for supersonic research and was the first such tunnel in the world and a breakthrough. The Collier Trophy was awarded in 1951 to "John Stack and 19 associates at Langley Aeronautical Laboratory, NACA, for the conception, development and practical application of the transonic wind tunnel throat."



NASA/Jasim Ahmad and Tim Sandstorm

This colorful image is a Computational Fluid Dynamics simulation of a full-scale UH-60A rotor from a Black Hawk helicopter in the giant 40-by 80-Foot Wind Tunnel at NASA Ames Research Center in Moffett Field, California. Colors represent pressure – red is high pressure and blue is low pressure.

Category 3: Tools of the trade

NASA Ames revolutionized design with CFD

NASA Ames Research Center in Moffett Field, California, engineers have worked for more than five decades to develop and improve the infrastructure to radically change how aircraft and spacecraft are designed.

Wind tunnels were the only way to do such computations until NASA Ames technological advancements in supercomputers, software and algorithms enabled simulation-based design and engineering using computational fluid dynamics, or CFD. CFD uses numerical methods and algorithms to solve or analyze challenges with fluid flows. The NASA Ames CFD solutions exponentially reduced the time and costs to look at new designs. It also permitted theoretical physics investigations, while creating information technology standards.

Ames researchers' vision included the creation of a Numerical Aerodynamic Simulator, which is now known as the NASA Advanced Supercomputing Division. It is a state-of-the-art facility where CFD experts, computer scientists, visualization specialists and network and storage engineers are under one roof in a collaborative environment.

Ames engineers also created what are now routine programs that industry uses for solving complex challenges. For example, rotorcraft aerodynamics was modeled as a result, as were two design analysis cycles of the Space Launch System and its launch environment.

Category 4: Safety

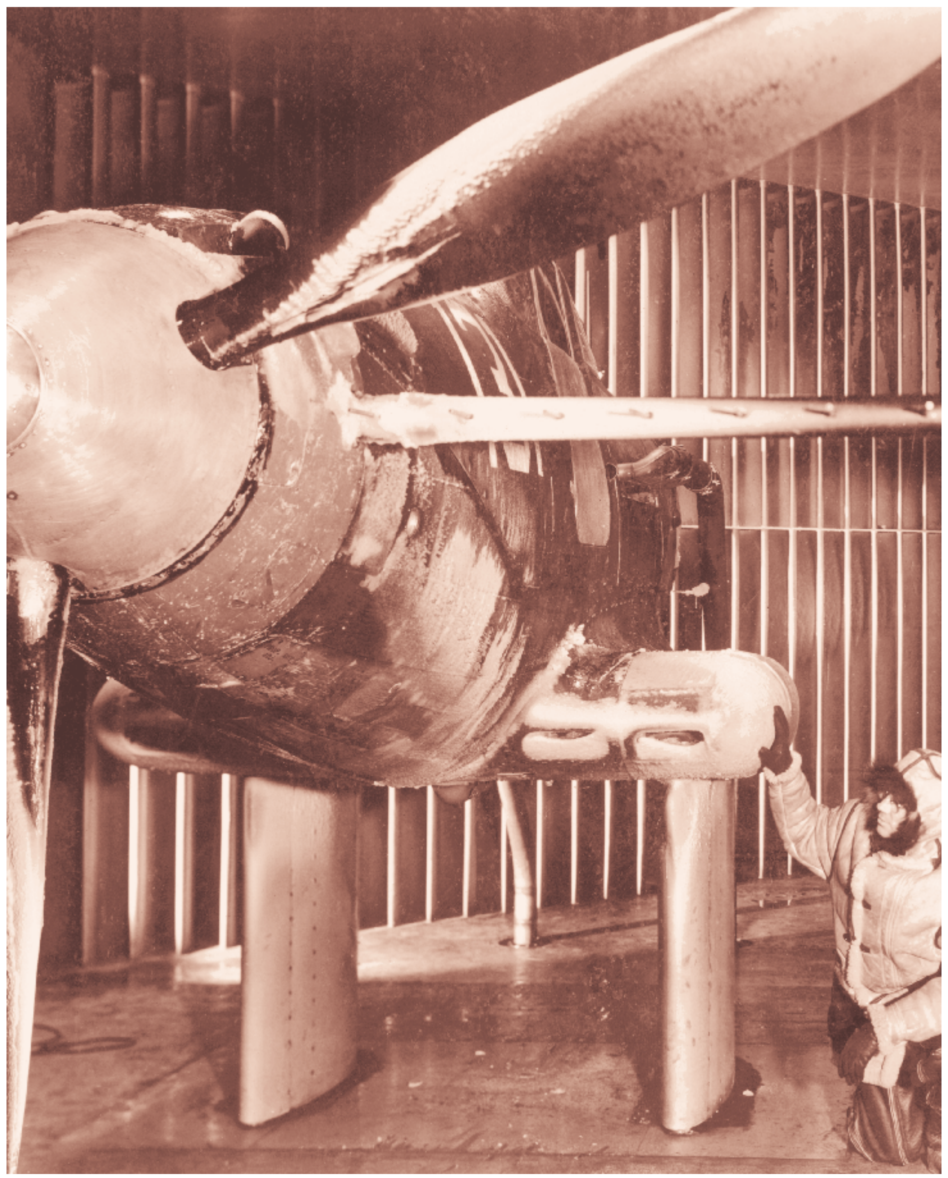
Thermal de-icing systems improve safety

Lewis Rodert began working on solving aircraft icing problems in 1928 using a wind tunnel and flying wing samples, as well as talking with pilots. By 1931 thermal de-icing was the strongest solution.

Most researchers thought ice added weight, keeping the pilot from climbing above the icing weather. Rodert argued that ice incapacitated crucial aircraft parts such as wing leading edges. The NACA built an icing tunnel at Ames Research Center in Sunnyvale, California, to study this in 1937. The NACA believed nothing should restrict where an aircraft flew.

Using a new Lockheed 12A with the wings' leading edge modified to be heated by engine exhaust, the NACA flew the aircraft into known icing conditions during research that spanned several years. Among the significant findings were that considerably less heat was required than expected to de-ice a wing. Another was that de-icing fluids did not work as well as believed. The U.S. Navy was so interested it had draftsmen copy the 12A design and apply it to the PBY-2 aircraft in use in the Aleutian Islands.

Thermal de-icing systems captured a Collier Trophy in 1946 for "Lewis A. Rodert, [NACA] for his pioneering research and guidance in the development and practical application of a thermal ice prevention system for aircraft."



GPN-2000-001452 NACA/NASA

Ice formations on the propeller and fuselage surfaces of a test unit installed on March 5, 1945, showed what could happen to an aircraft in flight under certain atmospheric conditions. The research was conducted in the Icing Research Tunnel at the NACA Aircraft Engine Research Laboratory in Cleveland (now known as NASA Glenn Research Center). Ice degrades the performance of an aircraft in flight and can cause loss of control.

ED12-0172-093 NASA/Tom Tschida

Banking hard to starboard after a very close pass near a ridgeline, the Dryden Remotely Operated Integrated Drone research aircraft provided good data for project engineers during flight tests of a miniature ground collision avoidance system for small, remotely piloted aircraft.

Category 4: Safety

NASA innovations lead to safer skies

For the Digital Fly-By-Wire project, NASA technicians replaced cables and push rods in a Navy F-8C with an electronic flight-control system coupled to a digital computer that interpreted the pilot's control inputs and transmitted them to electric motors to actuate aerodynamic control surfaces.

Flown between 1972 and 1985, the first phase of the program featured the same type of guidance computer used by Apollo astronauts to reach the moon. In the second phase the F-8 was used to validate flight control computers later used on the space shuttles. This technology has now become commonplace in both civil and military aircraft.

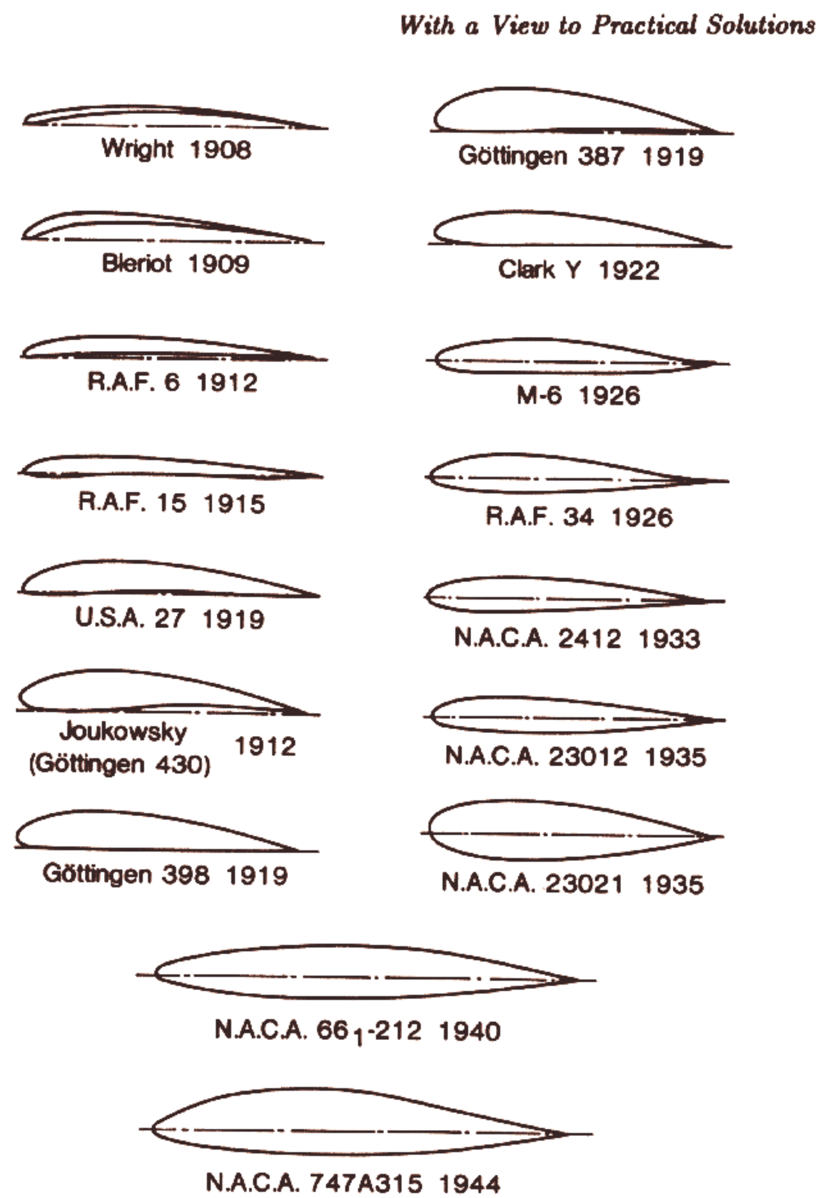
NASA has been jointly developing automatic collision avoidance technologies with the Air Force for nearly three decades. This culminated in 2014 with an Automatic Ground-Collision Avoidance System (Auto-GCAS) that could significantly reduce the incidence of controlled flight into terrain aircraft accidents. The new software, pioneered through a partnership between the Air Force Research Laboratory, NASA Armstrong and Lockheed Martin, is expected to have application to a wide variety of civil and military aircraft. Additional research is being undertaken at Armstrong using small, remotely piloted aircraft to test a smartphone-enabled Auto-GCAS.

Category 5: Airfoil design

NACA wrote the book on airfoils

Starting in the 1920s and continuing through the early 1930s the agency invested heavily in researching airfoils using the Variable Density Wind Tunnel. The results included 78 specific airfoils, identified by four digits that represented critical properties, matched to an airfoil cross-section.

Following its mandate to share its research as widely as possible, in 1933 the NACA published the data. Aircraft designers could now select a wing, such as NACA 2412 for example, that had specific – and demonstrated – characteristics for a given purpose rather than guess or experiment themselves. The NACA kept developing additional airfoil shapes, adding more digits to reflect more complex airfoils. NACA airfoils and their derivatives are still in use today.



The historical evolution of airfoil sections, 1908–1944. The last two shapes (N.A.C.A. 66₁-212 and N.A.C.A. 747A315) are low-drag sections designed to have laminar flow over 60 to 70 percent of chord on both the upper and the lower surface. Note that the laminar flow sections are thickest near the center of their chords.

GPN-2000-001299
NACA/NASA

The graphic represents the historical evolution of airfoil sections from 1908 to 1944. The last two shapes are low-drag sections designed to have laminar flow on more than 60 to 70 percent of chord on both the upper and lower surfaces.

NASA

The Cessna 210 Centurion was tested at the NASA Langley Research Center in Hampton, Virginia, in the Langley 30-by-60-Foot Full Scale Tunnel in 1985 following the company's successful flight test program.

Category 5: Airfoil design

NASA wrote the book on general aviation wings

NASA introduced new airfoil designs for general aviation aircraft in the early 1970s that enabled more efficient wings.

NASA's Low-Speed Airfoil Program began in 1972 with the development of the General Aviation (Whitcomb)-1, or GAW-1, airfoil. NASA engineer Richard Whitcomb's supercritical airfoil was the basis for the wing design that was flat on top and led to smoother airflow.

Aircraft manufacturers embraced the GAW-1 and used the 17-percent-thick, low-speed airfoil. The wing maximized lift, minimized low-speed drag and was more predictable than previous wing designs. A NASA technical report first announced the airfoil and was so well received that a second printing was needed.

Next came a 13-percent-thick airfoil, called GAW-2, and it sparked a series of wing designs with varying thickness. NASA engineers validated the new airfoils with wind tunnel and flight tests. Additional airfoils are still added to the airfoil database under the designation of LS, or low-speed, airfoil. The database allows designers to decide the wing's purpose and use that information to determine its shape and thickness.

Category 6: Design innovations

Area Rule defined aircraft efficiency

Aerodynamicists became familiar with transonic drag before World War II but had no effective way of exploring the phenomenon, which typically manifests itself between Mach .8 and Mach 1.2.

Inspired by a talk, and gifted with a keen intellect and unbounded curiosity, Richard Whitcomb took advantage of the newly created slotted-throat transonic wind tunnels and explored the issue. He found that narrowing an aircraft's fuselage at the point of its greatest cross section – the wing's intersection – was critical to reduce this drag.

Meanwhile, the Air Force was confronted with the inability of the F-102 to exceed Mach, which it was designed to do. Whitcomb applied what he'd discovered in the wind tunnel to the aircraft's shape, dubbed the 'coke bottle' or 'wasp waist,' and the drag was sufficiently reduced that the jet exceeded Mach. The Area Rule, as the result was called, is the standard rule of efficiency, and earned the NACA and Whitcomb the Collier Trophy in 1954. The citation read, "For discovery and experimental verification of the area rule, a contribution to base knowledge yielding significantly higher airplane speed and greater range with same power."

GPN-2000-001262 NACA/NASA

Richard Whitcomb examined a model designed in accordance with his transonic area rule in the 8-Foot High-Speed Tunnel in April 1955.

EC73-3468 NASA

NASA used a Vought F-8A Crusader aircraft for installation of an experimental Supercritical Wing in place of the conventional wing. The unique design of the wing reduced the effect of shock waves on the upper surface near Mach 1, which in turn reduced drag. The use of such airfoils is common on modern aircraft.

Category 6: Design innovations

NASA research revolutionizes aircraft wings

In order to explore NASA aeronautical engineer Richard T. Whitcomb's theories regarding supercritical airfoils, a Vought F-8A was modified with experimental wings. The supercritical wing was shaped to modify shock-wave formation and associated boundary-layer separation, thereby delaying the typically sharp increase in drag that occurs as an airplane approaches the speed of sound. Such a delay makes the airplane more fuel-efficient by increasing its speed or range, or decreasing fuel consumption. The modified aircraft was first flown in March 1971. Supercritical airfoils are now widely used throughout the world on civil, commercial and military aircraft.

When the price of aviation fuel spiraled upward in 1974, Whitcomb initiated analytical studies and wind-tunnel tests at the Langley Research Center to see if the addition of winglets – vertical airfoils on the wingtips – would effectively reduce drag by interacting with wingtip airflow circulation and vortices. The impressive results of Whitcomb's studies were disseminated to U.S. civil and military communities at a meeting on transport technologies in 1978. Over the next several years winglets were installed and tested on modified KC-135A at NASA Dryden (now Armstrong), validating Whitcomb's concept and demonstrating a 6.5 percent increase in fuel efficiency.

April 2015

NACA Snap shots

A look at the NACA work here

By Peter W. Merlin
NASA Armstrong Public Affairs

Now known as NASA Armstrong Flight Research Center, the facility was first established by the National Advisory Committee for Aeronautics, or NACA, NASA's predecessor, on Sept. 30, 1946.

It began as a detachment of the NACA Langley Memorial Aeronautical Laboratory in Hampton, Virginia, that was deployed to Muroc Army Air Field (now Edwards Air Force Base) at Rogers Dry Lake in the heart of California's Mojave Desert. The NACA Muroc Unit was comprised of scarcely more than a dozen members: engineers, technicians, pilots, administrative personnel and human computers assigned to test the Bell X-1, the first supersonic airplane.

The remote desert post was initially intended to be temporary but on Sept. 7, 1947, NACA director of aeronautical research Hugh L. Dryden officially established a permanent facility named the NACA Muroc Flight Test Unit. For the next two years it was managed by Langley until becoming independent on Nov. 14, 1949, at which time it was renamed the NACA High-Speed Flight Research Station.

Increasing numbers of projects and personnel necessitated relocating the entire facility to the northern end of the lakebed. The new location was inaugurated on July 1, 1954, as the NACA High-Speed Flight Station. Establishment of the National Aeronautics and Space Administration on Oct. 1, 1958, mandated a simple name change to the NASA High-Speed Flight Station. Less than a year later on Sept. 27, 1959, the facility's name was changed to the NASA Flight Research Center, elevating the facility to full center status and reflecting the broader scope of aeronautical research.

E70-21427 NACA/NASA

The original group that comprised the NACA Muroc Unit in 1946 pose in front of the X-1 and the B-29 that air launched it.

E49-005 NACA/NASA

Robert Champine, left, and Herbert Hoover were two NACA pilots who flew the Bell Aircraft Corporation X-1. Hoover was the first NACA pilot to fly faster than the speed of sound. Capt. Charles E. "Chuck" Yeager, a U.S. Air Force pilot, first broke the sound barrier on Oct. 14, 1947.

E49-0054 NACA/NASA

Human computers processed early flight research in the 1940s and 1950s.

E-2820 NACA/NASA

The B-50 launches the X-2. In the background are South Base facilities.

The hangar and a building to its right in the background image made up the NACA facilities prior to the reestablishment of the NACA on its current location on North Base. The image is enlarged from E-51-503.

E58-3793A NACA/NASA

The D-558-II flies a research mission.

E-1152 NACA/NASA

The NACA D-558-II is shown here with its test force, the P2B-1S (the Navy version of the B-29) that air launched the aircraft and two F-86 chase aircraft. NACA pilot Scott Crossfield is standing at the nose of the D-558-II and was the first pilot to reach Mach 2.

E67-17348 U.S. Air Force

***Above**, the X-3 Stiletto flies a research mission. The aircraft made significant contributions to knowledge about inertial coupling.*

***At right**, NACA High-Speed Flight Station test pilot Joseph Walker is photographed with the Bell Aircraft Corporation X-1A in 1955.*

E-1758 NACA/NASA

EC00-277-15 NASA?Tony Landis

Pilots Ed Schneider, left, and Rogers Smith, right, visit with Bob and Gloria Champine by a P-51 that Bob Champine flew for the NACA.

E52-0173 NACA/NASA

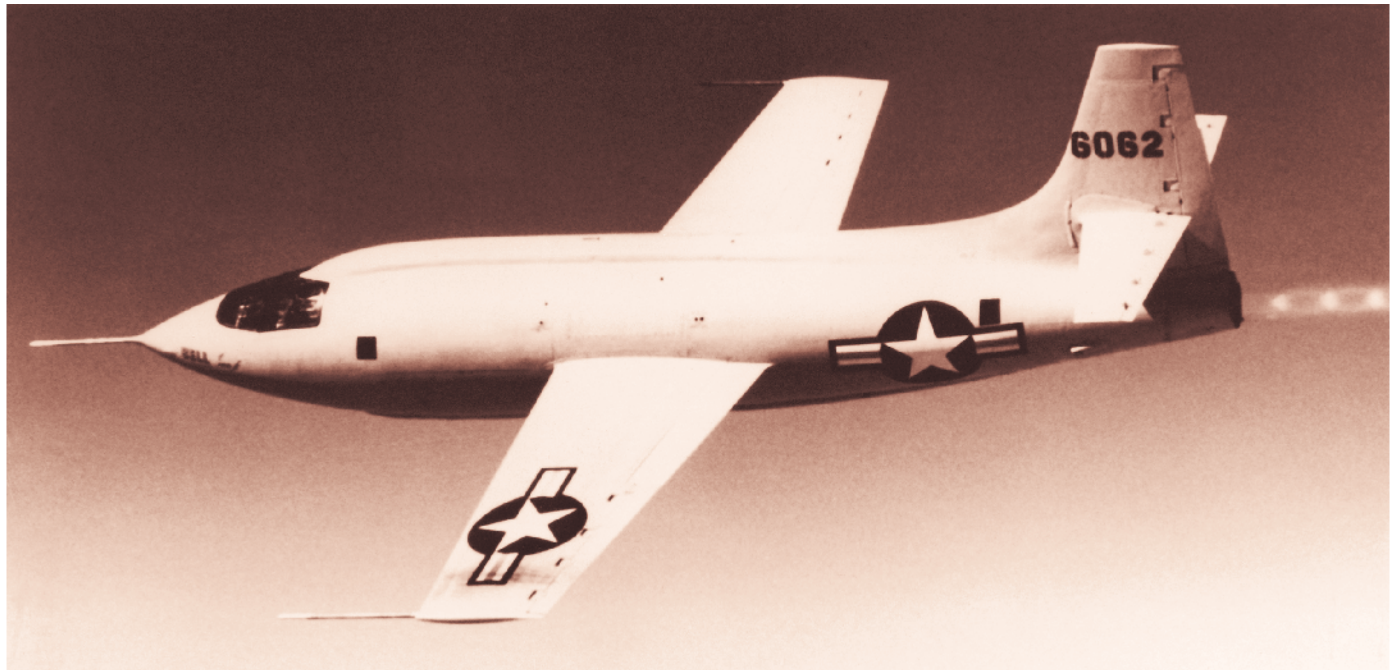
The D-558-I flies a research mission.

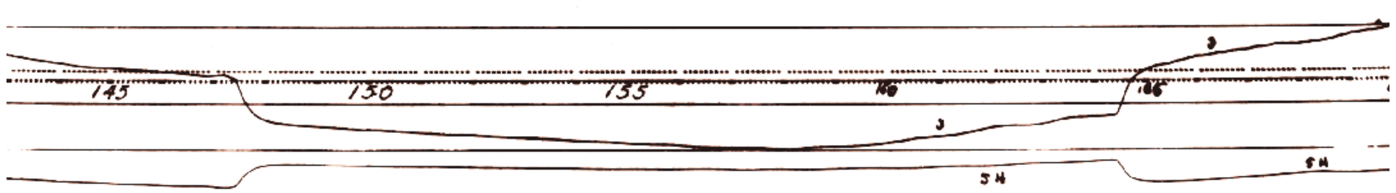
E-2305 NACA/NASA

Hubert Drake discusses a pending flight plan.

E53-1096 NACA/NASA

Station Director Walter Williams, D-558-II pilot Scott Crossfield and director of flight operations Joseph Vensel talk following the first Mach 2 flight on Nov. 20, 1953.





E60-6204A NACA/NASA

The Bell Aircraft Corporation X-1 No. 1 in flight. Below the flight is a copy of the "Mach jump" paper tape data record of the first supersonic flight.

Category 7: High speed

X-1 pierced the sound barrier for the first time

The NACA's high-speed research began well before World War II and had its roots in the wind tunnels it operated. It also produced the world's first images of shock patterns on a wing section via schlieren photography in 1934.

The NACA teamed with the Army Air Force on a supersonic research project eventually known as the Bell X-1. John Stack and John Becker of Langley were instrumental in design work of the first aircraft to exceed the speed of sound on Oct. 14, 1947. Thus began a long commitment to high-speed flight and the agency branch in the desert (now Armstrong) was responsible for instrumenting the aircraft and reading the data. The NACA proved U.S. Air Force pilot Capt. Charles E. "Chuck" Yeager had exceeded Mach 1.

X-1 high-speed flight and instrumentation was recognized with a Collier Trophy in 1947: "John Stack, research scientist, NACA, for pioneering research to determine the physical laws affecting supersonic flight, and for his conception of transonic research airplanes." He was included along with Yeager and Larry Bell.

EC04-0092-39 NASA/Jim Ross

The X-43A hypersonic research aircraft and its modified Pegasus booster rocket accelerate after launch from NASA's B-52B aircraft over the Pacific Ocean on March 27, 2004. The mission originated from NASA Dryden (now Armstrong). Minutes later the X-43A separated from the Pegasus booster and accelerated to its intended speed of Mach 7.

Category 7: High speed

X-43A gave a glimpse into Mach 10 flight

NASA made aviation history in 2004 with the first and second successful flights of a scramjet-powered airplane at hypersonic speeds – those greater than Mach 5 or five times the speed of sound.

Researchers worked for decades to demonstrate scramjet technologies in wind tunnels and with computer simulations, culminating in the X-43A flights. A scramjet is a supersonic combustion ramjet and neither engine has moving parts. Both engines are essentially venturi tubes into which air flows, is compressed, fuel is atomized, combustion takes place and everything is exhausted as thrust. The key difference is the incoming air remains supersonic as it passes through the combustion chamber in a scramjet, while a ramjet flying supersonically must decelerate the air entering the combustion chamber in order for combustion to occur. The gain of a scramjet over any conventional engine is that it flies much faster (up to Mach 15) and higher than a ramjet, but only carries fuel, unlike a rocket which must also carry oxidizer.

Mach 6.8 was reached in March and Mach 9.6 was obtained in November. Guinness World Records recognized both on their website and in the 2006 edition of their book of records. Prior to the X-43A flights, a ramjet-powered missile that achieved slightly more than Mach 5 held the record. The highest speed attained by a rocket-powered airplane, NASA's X-15 aircraft, was Mach 6.7. The SR-71, the fastest air-breathing, crewed vehicle, achieved more than Mach 3.

NASA Langley and NASA Dryden (now Armstrong) jointly conducted the X-43A flights. Langley was lead center, responsible for hypersonic technology development. Armstrong was responsible for flight research, hardware integration and testing.

E58-3995 Douglas Aircraft Company

The D-558-II flies a mission. The D-558-II was the first aircraft to fly speeds of Mach 2 and above.

Category 8: Innovative aerodynamics and controls

Swept wing research enabled high-speed flight

In 1945 Robert T. Jones (then of Langley) argued for the benefits of swept wings on high-speed aircraft to delay the onset of shock waves and drag on the wings. He was unaware that a German aeronautical engineer, Adolph Busemann, advanced the same idea 10 years earlier. Busemann came to the U.S. after World War II and his work was not well known in the U.S. largely because of the war and secrecy of the work.

Jones' swept-wing theory was entirely independent. The agency had done some preliminary research on moderately swept wings and published the research in 1937. The NACA began testing swept-wing aircraft with the Douglas D-558-II aircraft in 1949 and used the aircraft to sort out the difficulties, dangers and hazards of the planform. The research was vital for virtually all subsequent military and civilian high-speed aircraft, deriving such valuable information as the ideal sweep for subsonic high-speed flight of about 35 degrees.

EC89-0096-240 NASA

Smoke generators and yarn tufts were used for flow visualization studies on an F/A-18 during the High Alpha Research Vehicle project.

Category 8: Innovative aerodynamics and controls

NASA research redefines control technologies

With Air Force and industry partners, NASA Armstrong has pioneered several important innovations in aerodynamics and flight control systems. In 1987, NASA modified an F/A-18 fighter aircraft as a High Alpha Research Vehicle, or HARV, to demonstrate stabilized flight at angles of attack between 65 and 70 degrees using thrust vectoring vanes, a research flight control system and (eventually) forebody strakes. By 1996, the HARV had completed 385 research flights.

From 1996 to 2005, NASA researchers worked with the Air Force Research Laboratory, or AFRL, and The Boeing Phantom Works on a high-tech adaptation of the Wright brothers rudimentary "wing-warping" approach to aircraft flight control. The Active Aeroelastic Wing flight research project focused on developing and validating the concept of controlling aircraft roll by twisting a flexible wing on a full-size aircraft, yet another modified F/A-18A.

In 2014, NASA and AFRL began the Adaptive Compliant Trailing Edge flight research project to determine if advanced flexible wing flaps can both improve aircraft efficiency and reduce airport-area noise generated during takeoffs and landings.

E58-03583 NACA/NASA

A technician examines an X-1B reaction control simulation that used hydrogen peroxide.

Category 9: Systems

HSFS' RCS enables maneuvers in space

In 1955 a small group of engineers at the High-Speed Flight Station (now Armstrong) used an Air Force Goodyear Electronic Differential Analyzer, or GEDA, and ran a simulation of a reaction control system. The RCS included small thrusters, which would fire to stabilize or redirect a vehicle in a near vacuum.

It was anticipated that the X-15 rocket plane could benefit from an RCS and resolve a challenge before it materialized. The X-15 was expected to reach 250,000 feet altitude, where dynamic pressure would render aerodynamic controls useless. The X-15 exceeded 354,000 feet during the program's 199 research flights.

From the GEDA the engineers applied their experience to a pivoted I-beam powered by pressurized nitrogen and had the station's pilots "fly" it. They adapted the system to the Bell X-1B using hydrogen peroxide thrusters and when that aircraft had to be grounded, the system was relocated onto the center's F-104 aircraft. The testing and validating of the RCS resulted in a system that worked not only on the X-15, but also on Mercury, Gemini, Apollo and the space shuttles.

Category 9: Systems

FOSS exponentially improved data collection

NASA Armstrong researchers have developed a sensing system with fibers that are the diameter of a human hair and can take thousands of strain measurements in real time.

The ideas for a fiber optic sensing system, or FOSS, originated at Langley and Armstrong. Researchers matured the concepts into a patented technology. The system is lightweight and robust and can determine the shape of an aircraft's wing in flight, monitor the structural integrity of bridges and pipelines and has spacecraft applications.

For example Armstrong technicians will instrument and collect data on the Cryogenic Orbital Test bed, which could lead to reductions in the system's size and cost, while adding reliability.

Kennedy Space Center in Florida is also funding an effort to use the FOSS technology on an expendable launch vehicle. That multi-center effort also relies on a partnership NASA Armstrong is developing with NASA's Marshall Space Flight Center in Huntsville, Alabama, to determine how to integrate the fiber optic sensors onto a rocket.

ED08-0109-07 NASA/Tom Tschida

The fiber-optic shape sensing, or FOSS, system was originally flight tested on NASA Armstrong's Ikhana aircraft. Clockwise from left, Anthony "Nino" Piazza, Allen Parker, William Ko and Lance Richards installed the system. The center's current fiber optic team won the R&D 100 award for their work, the equivalent of the Oscars of technology.

E-810 NACA/NASA

This NACA High-Speed Flight Research Station photograph of the X-5 was taken at South Base. The photograph, a multiple exposure, illustrates the X-5's variable swept wing capability.

Category 10: X-Planes

Redefining the boundaries of flight

The Research Airplane Program was a joint effort by the NACA and the military services. It was conceived near the end of World War II to perform flight research with a series of specialized aircraft in the then-unexplored realms of transonic and supersonic flight.

Two general categories of aircraft were obtained: Those needed to explore new areas of performance and those to investigate the effects of different airplane configurations. Such craft provided important information on new aircraft characteristics, validated wind-tunnel test data and analytical techniques and provided confidence in the achievement of safe, controllable, transonic and supersonic flight.

The "X" designation was used to denote aerospace vehicles designed for testing highly experimental configurations. The X-1 is the first and perhaps best known of the X-Planes, being the one to first exceed Mach speeds, but others followed that made equally important contributions to aviation. The X-5 was the first aircraft to explore variable incidence wings in flight (swing wing) while the D-558-II, technically not an X-Plane because it was a Navy aircraft, was used to explore issues of swept-wing, high-speed flight for the first time.

EC88-0180-1 NASA

The X-15 No. 2 was launched from the NASA's B-52B and its rocket engine ignited. The white patches are frost from the liquid oxygen used in the propulsion system, although very cold liquid nitrogen was also used to cool the payload bay, cockpit, windshields and nose. The X-15 is considered one of the most successful research programs, which included 199 flights.

Category 10: X-Planes

X-Planes expanded the frontier of flight

Nearly 70 years later, the "X" designation series has progressed to X-56. Though not all such research vehicles have X designations, they have come to be known collectively as the X-Planes. NASA's many experimental aircraft have been used to explore new regimes of flight and to develop advanced design technologies and flight control systems.

The hypersonic X-15 rocket plane, which spanned the NACA and NASA eras, flew to the edge of space at hypersonic speeds while carrying an assortment of scientific and engineering experiments. A series of wingless lifting body vehicles provided baseline data that was used in development of the space shuttle.

Researchers flew the X-29 to explore the use of advanced composite materials in aircraft construction, variable-camber wing surfaces, forward-swept wings with a thin supercritical airfoil, close-coupled canards and digital fly-by-wire controls.

The X-31 was designed to improve fighter aircraft maneuverability using vectored thrust. A variety of small, remotely piloted vehicles demonstrated advanced flight control technologies for tailless aircraft; hybrid wing-body flight characteristics for reduced fuel burn, emissions and noise; air-breathing, hypersonic flight using a supersonic combustion ramjet engine; risk reduction for advanced spacecraft technologies and more.

E57-2889 NACA/NASA

The NACA X-Planes represented the first of their kind and included aircraft such as the X-3, center, and clockwise from lower left: the X-1A, D-558-I, XF-92A, X-5, D-558-II and X-4.

Category 11: The unusual

Separating the real from the imagined

The X-3, although not successful in the traditional sense, revealed inertia coupling to be more than theory. The shift in aircraft type, from piston engines and propellers with the mass at the nose, to jets typically placed deep in the fuselage and smaller wings, changed the location of mass in the airplane. The change affected how the airplane behaved in roll and pitch and when the two were combined they proved deadly. The X-3 was pivotal in solving this problem.

The X-5 was the first aircraft to have wings that could shift from straight to swept and was critical for advanced research in high-speed flight. The D-558-II was designed for transonic research with swept wings. Initially it had a turbojet and a rocket motor but the jet was eventually removed to make an air-launch vehicle to extend its flight range. It became the first aircraft to exceed Mach 2.

ECN-1606 NASA

In this 1967 NASA Flight Research Center photograph the Lunar Landing Research Vehicle is viewed from the front. This photograph provides a good view of the pilot's platform with the restrictive cockpit view like that of the actual lunar module that Neil Armstrong landed manually on the moon.

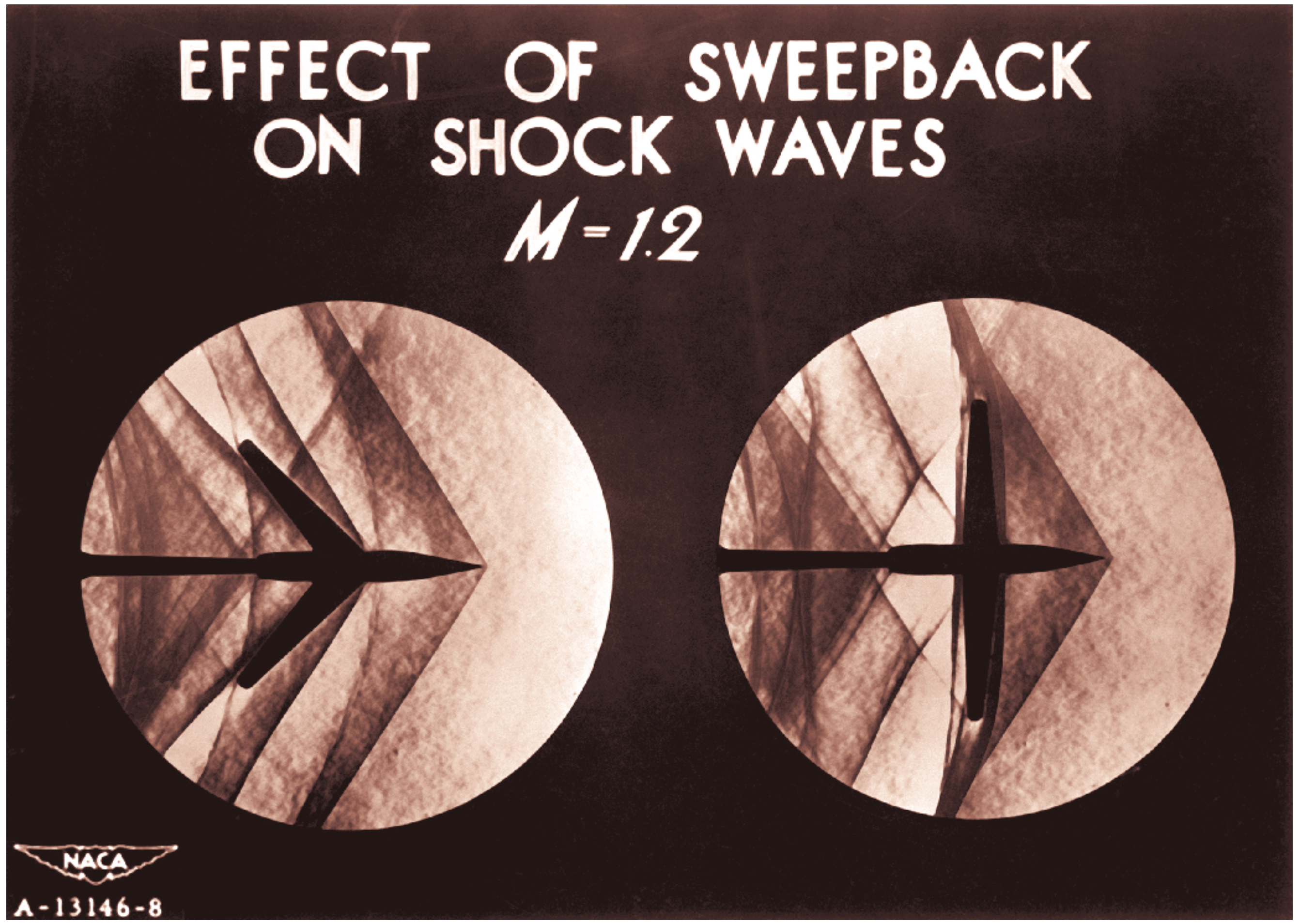
Category 11: The unusual

NASA has hosted some unusual birds

The Paraglider Research Vehicle, or Paresev, was towed skyward to 10,000 feet. It was built out of steel tubing, had three wheels, a seat and a fabric paraglider. It was designed as a possible solution to enable a Gemini capsule to make a controlled landing on skids and avoid an ocean splashdown. Modern hang gliders owe their design to the NASA Langley concept.

The LLRV was a spider-like shaped research vehicle used to simulate a lunar landing from 1,500 feet to the moon's surface. The LLRV led to the Lunar Landing Training Vehicle and Neil Armstrong credited those vehicles with his confidence to pilot the Eagle Lunar Module to take his first steps on the moon. The Eagle's computer was a key element in validating a digital fly-by-wire control system at NASA Dryden (now Armstrong). Most modern aircraft have a control system that originates from that work.

The solar-powered Helios resembled a flying yardstick with a wingspan of 247 feet, or longer than that of a Boeing 747-400. It flew slow and steady as its 14 motors, each as powerful as a hairdryer, propelled Helios to a record altitude for its class of aircraft at 96,863 feet on Aug. 13, 2001.



NACA/NASA

Schlieren photograph of airplane models showed the expulsion of flow sweepback on shock waves.

Category 12: Mission direction

NACA solved practical challenges

Long before it became a touchstone, the NACA began looking at what we call "Human Factors" as well as "Materiel Failure" in aircraft accidents. One of the earliest reports appeared in 1928.

In the 1930s the NACA modified the inboard leading edge of a DC-3, causing a disturbed airflow over the elevators as the aircraft approached a stall. The pilots could feel the disturbed airflow warning of the approaching stall, helping them to avoid it. Also in the early 1930s, researchers at Langley were the first to photograph shock waves developing over a wing in a high-speed wind tunnel using schlieren photography.

In 1952 the NACA began the design work for the world's first reusable spacecraft, the X-15. It was an aircraft conceived, designed and built during the NACA era and flown under NASA, and opened the door to human hypersonic flight.

In 1953 the NACA participated in a series of post crash fire studies for the first time, also looking at impact survivability in the cabins as part of the studies.

ED14-0341-50 NASA/Carla Thomas

NASA is using the remotely piloted Ikhana aircraft in the Unmanned Aircraft Systems in the National Airspace System project. The project is one of the nation's key research efforts for improving safety and reducing technical barriers and operational challenges associated with flying remotely piloted and autonomous aircraft in airspace shared by commercial and civil air traffic.

Category 12: Mission direction

Making way for a new class of aircraft

If remotely piloted and autonomous aircraft one day deliver groceries, determine optimal harvesting of crops, assist with natural disasters and monitor the environment and national borders, NASA deserves some of the credit.

NASA seeded emerging remotely piloted and autonomous aircraft systems that started literally in garages around the nation with programs like the Environmental Research Aircraft and Sensor Technology program in the 1990s and early 2000s.

ERAST spanned nearly a decade and provided funding for testing a new generation of aircraft that formed the basis for new missions that assisted the science community, developed new instruments and technologies and provided a cooperative environment for industry to share ideas and challenges.

NASA is continuing its support with the Unmanned Aircraft Systems in the National Airspace System program. While ERAST aimed at developing systems to see and avoid aircraft, look at new aircraft configurations and consider potential missions, the current effort aims to prove technologies and procedures and suggest rules to provide background for the Federal Aviation Administration to integrate this class of vehicles with piloted aircraft in the National Airspace System.