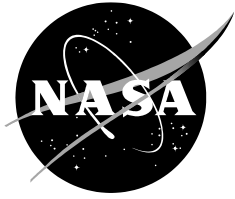


NASA/ SP-20210025857



NASA in Silicon Valley

*James N Anderson
Ames Research Center
Moffett Field, CA*

December 2021

NASA STI Program Report Series

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AMES RESEARCH CENTER
≡≡≡ ESTABLISHED 1939 ≡≡≡

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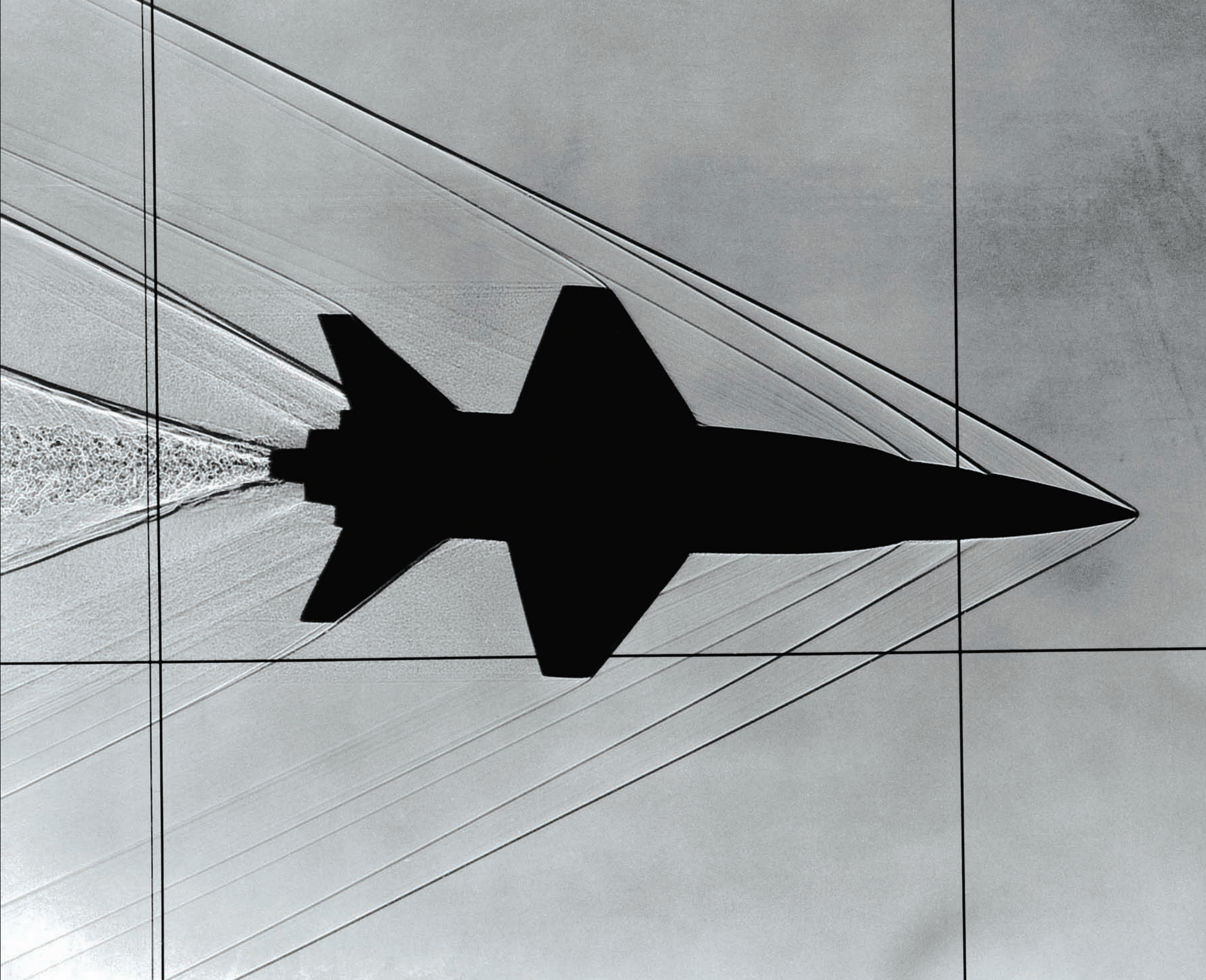
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Shadowgraph of an X-15 model. The X-15 flew to the edge of space and was integral to the early development of spaceflight.

A-25194
1959
Image credit: NASA





Preface

Whether looking back only a few years or more than a century, our world has been changing. Communication networks are more widespread and interconnected than at any other time in human history. Computing power that was only imagined a generation ago is now widely available and can fit in the palm of a hand. The miniaturization of the integrated circuit has brought us close to the limit of what is possible with silicon as we explore new possibilities in the quantum realm.

For over 80 years, NASA's Ames Research Center in California's Silicon Valley has held a special place amidst such change. With change, there also is continuity. Since 1939, Ames contributions have fundamentally shaped fields of study related to aeronautics and space.

The ingenuity and problem-solving capabilities of personnel at Ames have affected all our lives in numerous ways, from everyday air travel to how we envision the possibility of life on other worlds.

This publication is a mere hint at the rich history of Ames, told primarily through images that capture some of the recurring threads that have intertwined over that time. A bibliography points the reader to more detailed histories of Ames published over the years. They are excellent resources and, like all historical work, unavoidably incomplete. Our standing invitation in the present is to preserve what we can to help us understand where we are and how we arrived.

An illustration of Kepler-1649c, an Earth-size exoplanet discovered from reanalyzed data from NASA's Kepler space telescope, showing what its surface could look like. The Kepler mission confirmed that there are more planets than stars in our galaxy.

ACD20-0044-002

2020

Image credit: NASA/Daniel Rutter



1. Introduction

Ames evolved as a special place where state-of-the-art facilities and world-class talent melded to produce cutting-edge research in fields such as aerodynamics, thermodynamics, simulation, space and life sciences, and intelligent systems. Basic and applied research have been cornerstones of Ames since its founding as an aeronautical laboratory. That laboratory was an expansion of the first National Advisory Committee for Aeronautics, or NACA, facilities at Langley Aeronautical Laboratory in Hampton, Virginia, and it transitioned to research center with the advent of NASA in 1958.



Ames Aeronautical Laboratory.

A-13425

1940s

Image credit: NACA

Ames Research Center.

ACD17-0175-009

2017

Image credit: NASA/Dominic Hart



2. Breaking New Ground

On Dec. 20, 1939, just two months after a committee chaired by Charles Lindbergh selected the location, the first spade of dirt was overturned to inaugurate the construction of the new laboratory. A wooden shack served as an office for planning the construction of the first facilities at Ames. Those first facilities – which included a flight research hangar and a few wind tunnels – could not have been built at Langley. Langley had run out of available space and was experiencing a shortage of adequate electrical power. A new site was essential if aeronautical research in the United States had any chance of developing.

One of Ames' first wind tunnels – the 16-foot – enabled work that led to crucial design changes to aircraft during World War II. The tunnel stood until 2006, and in its place Ames broke ground on the new Biosciences Collaborative Laboratory. The facility houses laboratories to serve NASA's programs in fundamental space biology, astrobiology, and bioengineering. Where aerodynamicists once worked is a new space purposefully designed to facilitate interdisciplinary research. This will carry on the history of cutting-edge research, meet current needs, and advance NASA's strategic goals in both human exploration and science.



NASA officials join Ames Center Director Eugene Tu and the Amoroso Construction Northern California Operations Manager at a ceremony to begin construction on the Biosciences Collaborative Laboratory. The facility held its ribbon-cutting ceremony in February 2020.

ACD17-0158-004

August 22, 2017

Image credit: NASA/Donald Richey

Russell Robinson momentarily looks to the camera while supervising the first excavation at what would become Ames Research Center.

G-32-0-82

December 20, 1939

Image credit: NACA

82(12-20-39-9) PHOTO NACA CONSTRUCTION M.F. CALIF



3. World War II

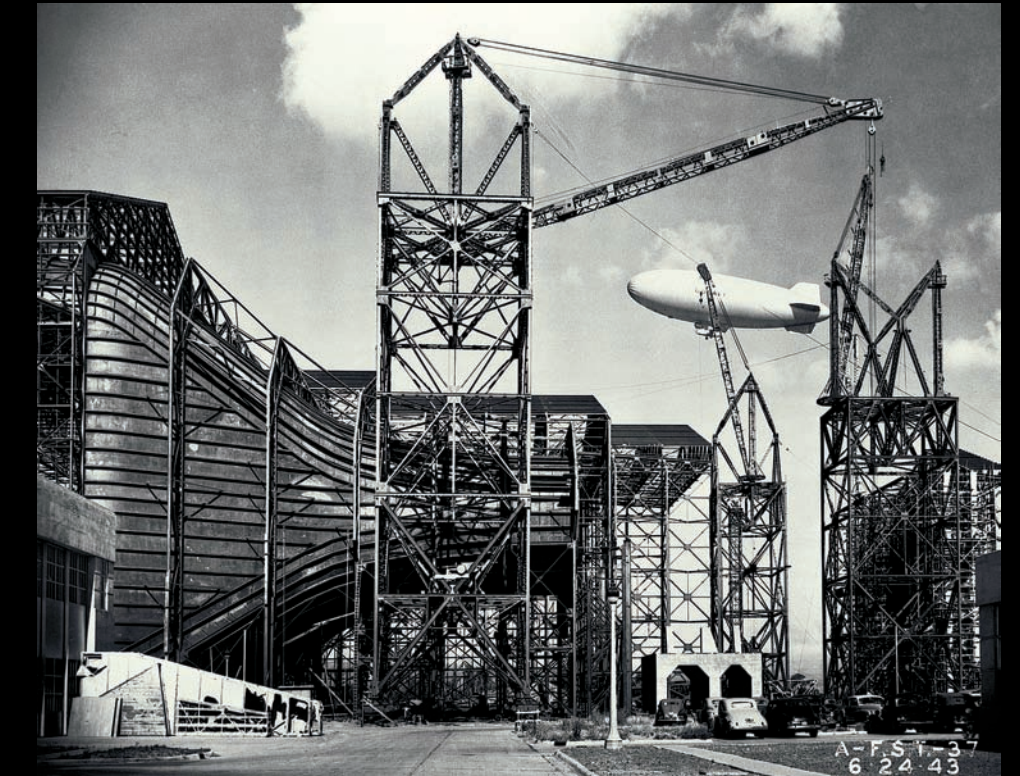
Quick and elegant solutions to potentially deadly problems characterized the crucial design changes to aircraft proposed and tested at Ames. One of the most important fighter aircraft of the time, the P-51B Mustang, had a problem known as “duct rumble” solved in the 16-foot wind tunnel, which was then the fastest tunnel in the NACA.¹ Engine buffeting and icing were addressed and ameliorated during the war, bolstering Ames’ reputation as a place where clever and economical answers could be found to challenging problems.

Two women working as “computers” use slide rules and calculating machines to process data from the 16-foot wind tunnel. Data generated in the wind tunnels were meaningless without proper processing. Before Silicon Valley, Ames’ history of computing begins with the people who ensured that world-class facilities could meet their potential.

AAL-4951

1943

Image credit: NACA



Construction of the world's largest wind tunnel and its original 40- by 80-foot test section. A later expansion created an additional 80- by 120-foot test section. A Navy blimp, which would have been based at Hangars 2 and 3 at Moffett Field, patrols in the background.

AFST-37

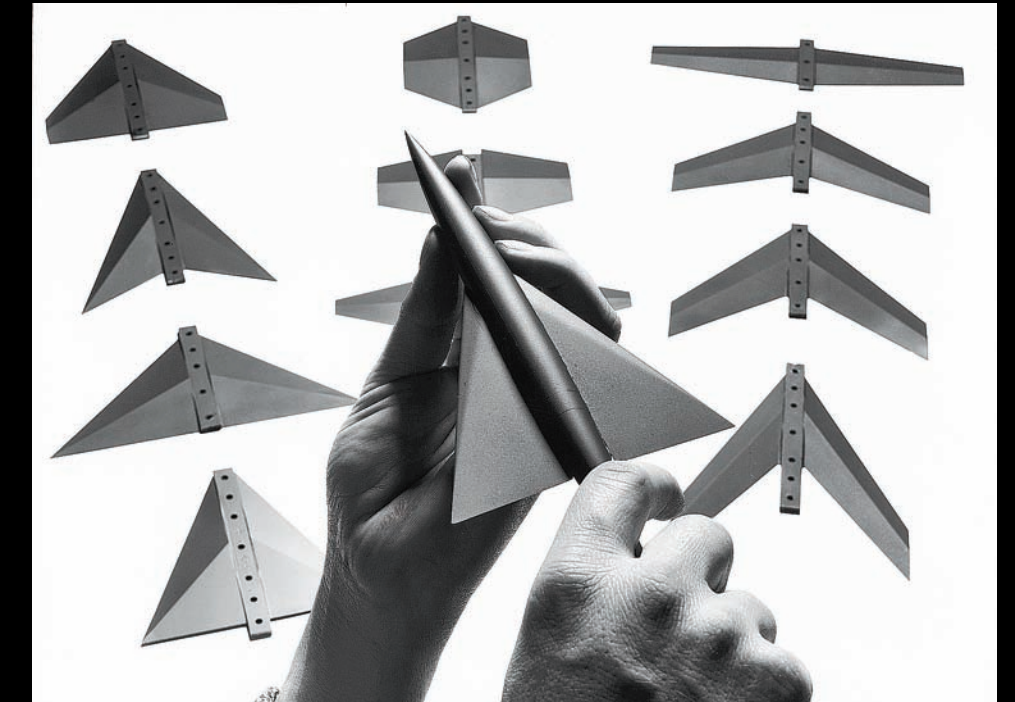
1943

Image credit: NACA



4. Aeronautical Ingenuity

After World War II, aerodynamicist R.T. Jones transferred from Langley to Ames. Jones had conceived of the swept wing just before the end of the war, independent of similar work that had progressed in Germany.² A design insight of fundamental importance to high-speed flight, the swept wing remains with us today and is incorporated into most commercial aircraft. As supersonic flight became a reality, Jones devised a design method known as the supersonic area rule that reduces the drag aircraft encounter above the speed of sound. Jones also advised his fellow NACA researchers, who designed inventive and more efficient supersonic wing models for testing at high Mach numbers. Later in his career, Jones developed an unconventional concept that was successfully flight tested: the oblique wing. Those flights, in addition to wind tunnel data, generated insight into its handling, safety, and fuel efficiency. While the oblique wing did not become commonplace like the swept wing, another unconventional Ames innovation has proven to be indispensable in the even higher speed regime of reentry.



Wind tunnel models displaying various planforms – the shape of an airplane's silhouette when viewed from above – designed for early supersonic flight.

A-13703

1948

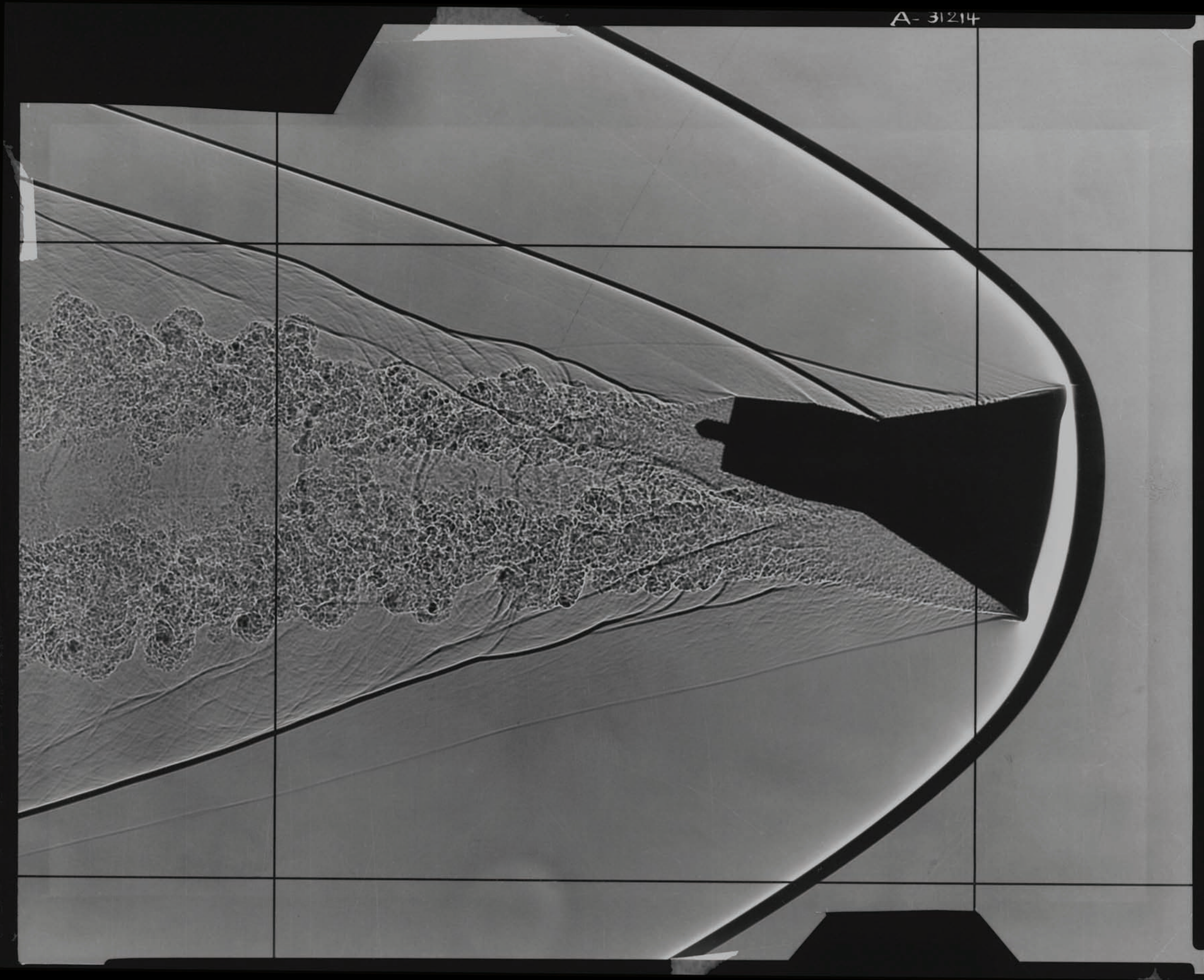
Image credit: NACA

The Ames-Dryden 1, or AD-1, oblique wing aircraft in flight with its wing swept at 60 degrees.

EC81-15846

1981

Image credit: NASA



5. The Blunt Body Concept

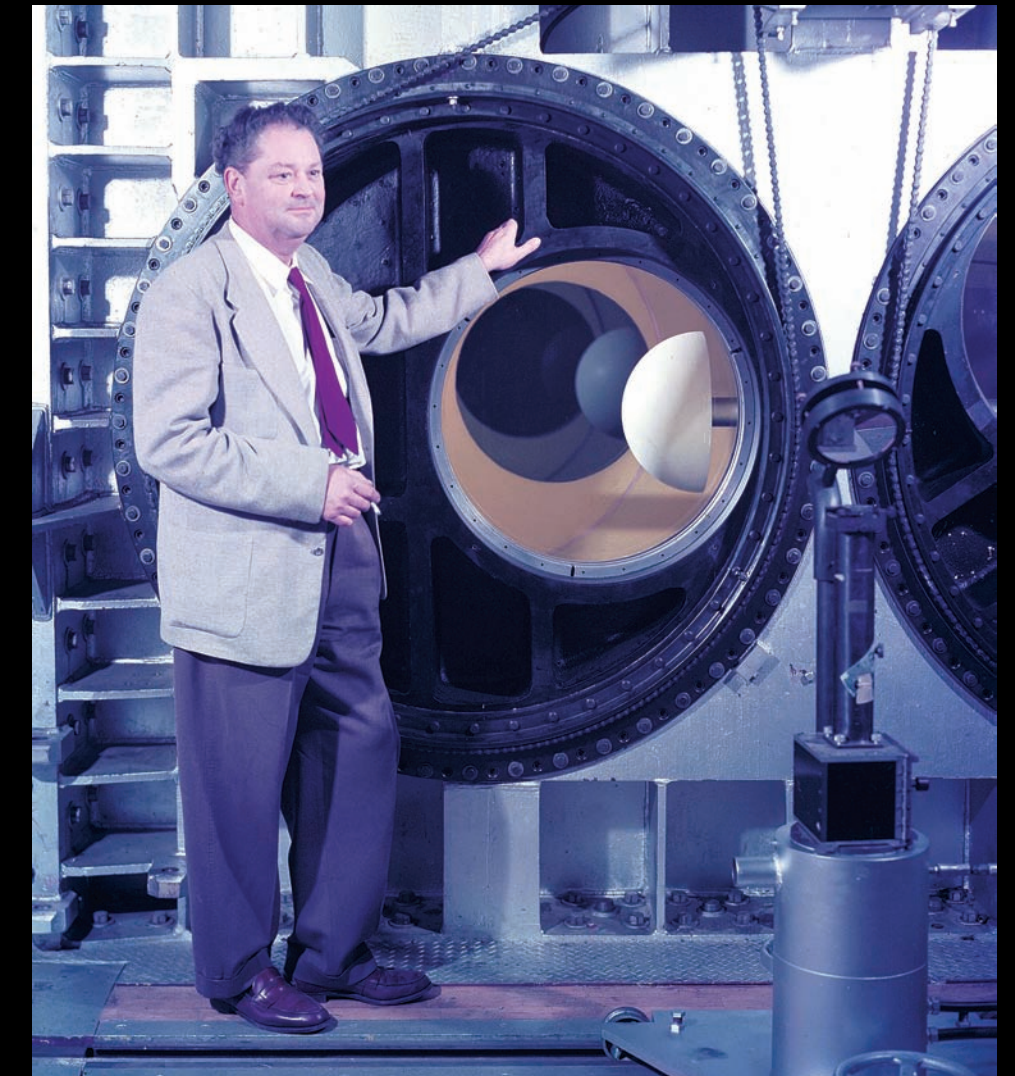
One of the most enduring and counterintuitive innovations to come out of Ames is the blunt body concept. In the 1950s, a component of the Cold War arms race involved testing missiles for their flight properties. In addition to the development of conventional arms, reentry conditions proved to be a major obstacle for intercontinental ballistic missiles that were intended to carry nuclear warheads. The pointed nose cone shapes that worked so well aerodynamically at certain speeds could not withstand the thermodynamic heating that resulted during reentry. In 1953, H. Julian "Harvey" Allen and Alfred Eggers published a paper³ suggesting a blunt shape for reentry into Earth's atmosphere could help prevent burning up. A blunt tip changed the way that the atmosphere around a capsule became hot, which proved crucial for returning astronauts safely to Earth. The blunt body concept has been incorporated into the capsules and probes that must survive atmospheric entry, whether on Earth or another world.

A shadowgraph of a Gemini capsule model during a flight stability test.

A-31214

1963

Image credit: NASA/Gaeton Faraone



H. Julian "Harvey" Allen stands in front of an early model testing his blunt body concept in the 8- by 7-foot supersonic test section of the Unitary Plan Wind Tunnel.

A-23438

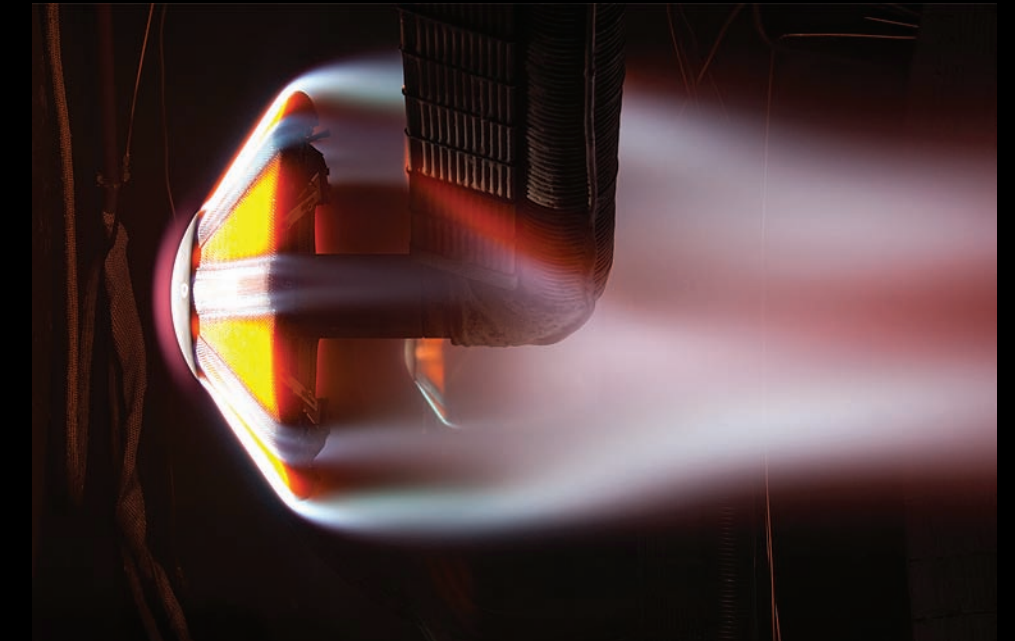
1957

Image credit: NACA



6. Entry, Descent, and Landing

Ames continues to innovate ways to enter atmospheres safely and more efficiently, such as by extending the blunt body concept into a collapsible aeroshell design that can be stowed for launch and unfolded when needed. Beyond aeroshells and parachutes, entry, descent, and landing, or EDL, includes both the hardware and software required for some of a mission's most intense moments just before landing. Ames is a leader within NASA from the design to the testing of these systems.



The blunt body concept remains an integral part of cutting-edge reentry technology, seen here in this testing of the Adaptive Deployable Entry and Placement Technology, or ADEPT, in an Ames high-temperature plasma facility known as an arc jet.

ACD15-0179-010

2015

Image credit: NASA/Cesar Acosta

The parachute for the Mars Science Laboratory during a qualification test in the 80- by 120-foot wind tunnel at Ames. Parachutes are one of the most visible aspects of the descent and landing phases of a mission.

PIA11995

2009

Image credit: NASA



7. Vertical Flight

After the successful landing of the Perseverance rover for the Mars 2020 mission, the Mars Helicopter, Ingenuity, completed the first powered and controlled flight on another world. Ames and Langley provided significant flight performance analysis and technical assistance during Ingenuity's development. For Ames, its history of studying novel forms of vertical flight extends back to the days of the NACA. Ames expertise has influenced the development of the tools and techniques related to powered-lift, stability and control, vertical and short takeoff and landing, and tiltrotor aircraft, to name a few categories. Ames went on to develop a long and productive partnership with the Army, as the two cooperated in joint research in vertical takeoff and landing studies. Ames also struck an important agreement with the Federal Aviation Administration and the Department of Transportation to make its simulators available for qualifying checks on new commercial aircraft.⁴ Decades later, these collaborations continue. New and ongoing partnerships with government, academia, industry, nonprofits, and commercial space have been integral to the interdisciplinary strength that Ames' culture fosters.



The Mars Helicopter, Ingenuity, captures an image of its own shadow while hovering over the Martian surface on April 19, 2021. This was the first powered, controlled flight on another planet.

PIA24584

2021

Image credit: NASA/JPL-Caltech

The XV-15, the experimental tiltrotor that led to the V-22, an aircraft capable of taking off and landing like a helicopter and flying as a turboprop plane, takes off at Crows Landing in California's San Joaquin Valley.

AC82-0723-23

1982

Image credit: NASA/Roger Brimmer



8. Advanced Air Mobility

In recent years, drones have proliferated. With their widespread adoption come numerous challenges that must be addressed to ensure the continued safety and efficiency of airspace operations. Airspace is no longer only for large aircraft high above – it is overhead in urban environments and will soon hover just above our doorsteps. This will require even more intense management. As these new forms of flight become more common, including the air taxis and air cargo delivery drones that Advanced Air Mobility envisions, NASA leads the collaborative effort between government, industry, and academic partners to ensure they integrate the airspace safely and efficiently. Software development and simulation facilities at Ames are integral parts of this research.



The Aerospace Cognitive Engineering Lab Rapid Automation Test Environment at Ames showing out-the-window views of San Francisco for an Advanced Air Mobility ride quality simulation project.

ACD20-0006-074

2020

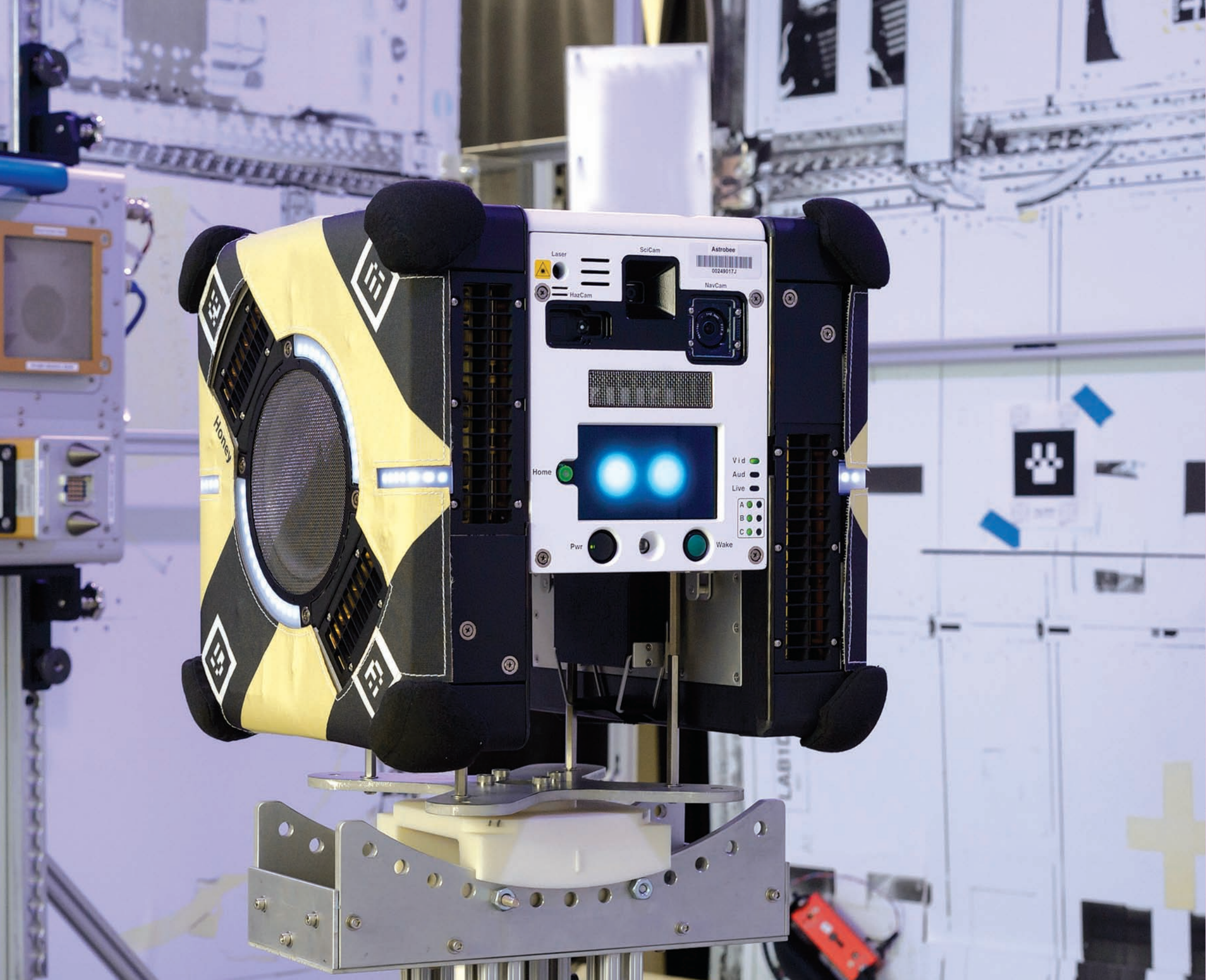
Image credit: NASA/Dominic Hart

Two of Ames' longtime strengths – supercomputing and computational fluid dynamics – come together in this visualization of the flow of NASA's six-passenger quadcopter concept for Advanced Air Mobility.

nas.nasa.gov

2019

Image credit: NASA/Patricia Ventura Diaz



9. Complementing Humans in Space

Ames' presence in Silicon Valley made it a natural location for early developments in virtual reality and telepresence. Software development and simulation at Ames continue to complement humans in space and on Earth, as Ames provides leadership in human systems integration and intelligent systems. Today, as NASA prepares for unprecedented missions, our spacecraft, space habitats, aircraft, planetary and space exploration platforms, and operations are becoming progressively more complex. To sustain these future complex systems, Ames is making critical advancements in novel system architectures, algorithms, and software tools. These new technologies function as advisors, advanced automation, and autonomous agents that are capable of adapting to changing conditions, knowledge, and constraints. In addition, Ames leads in information technology, conducting mission-driven, user-centered computational sciences research, developing and demonstrating innovative technologies, and transferring these new capabilities to NASA missions.⁵



The Virtual Interface Environment Workstation, an early VR technology.

AC89-0437-6

1989

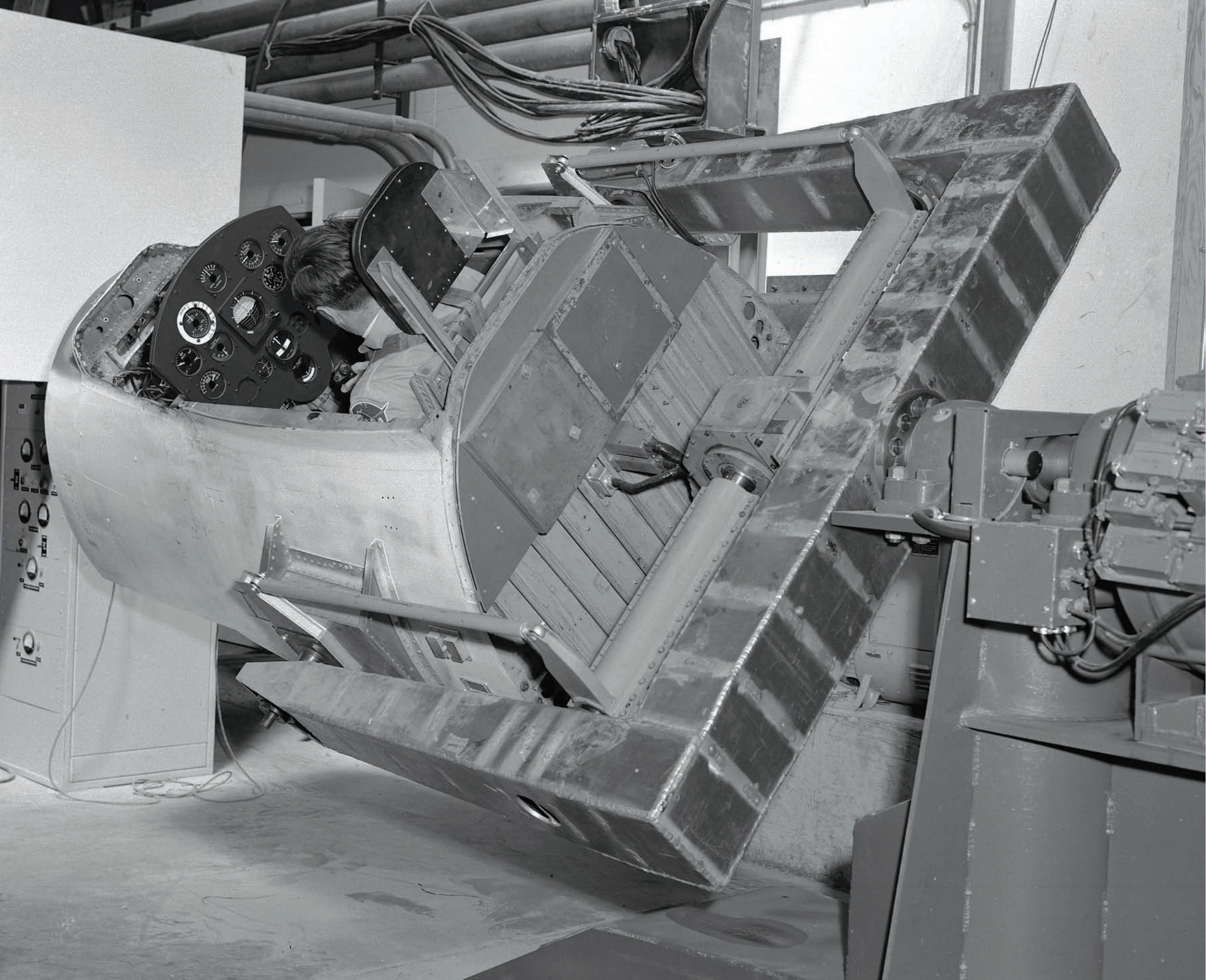
Image credit: NASA/Wade Sisler

Astrobee Honey flight unit and docking unit in the Automated Science Research Facility at Ames.

ACD18-0223-039

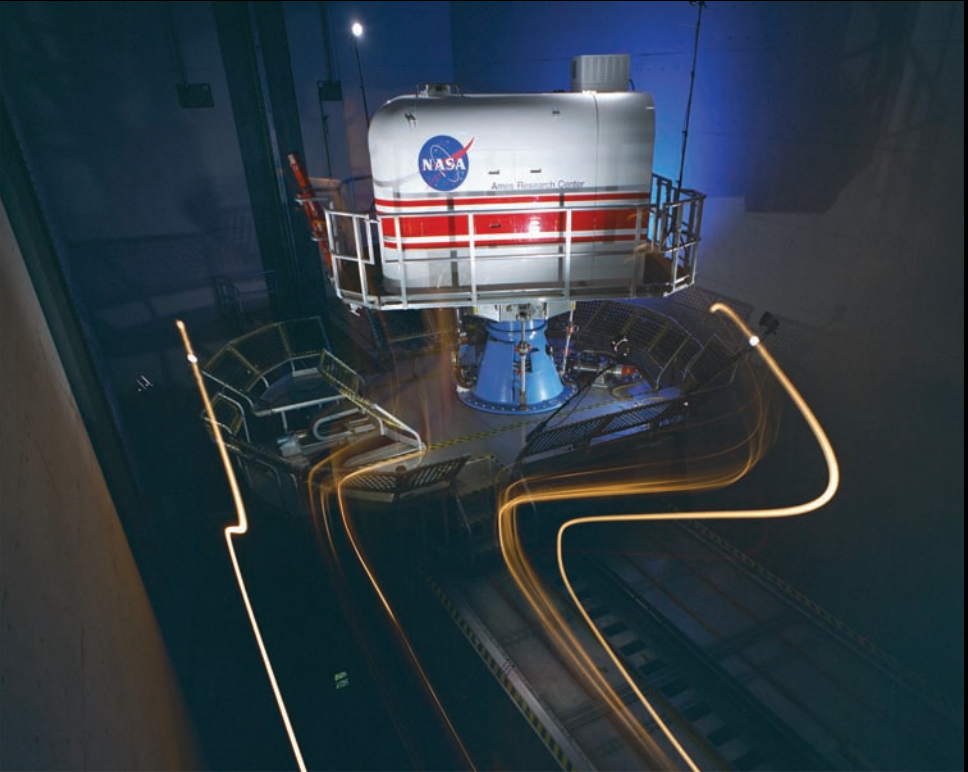
2018

Image credit: NASA/Dominic Hart



10. Simulation Hardware

The first electronic computer arrived at Ames in 1949, an early milestone in the later development of flight simulators at the center.⁶ Ames staff realized they could use the reprogrammable capability of those early analog computers to test a wide variety of configurations for aircraft, all on the ground. Between researchers using wind tunnel tests and actual flight research with test pilots, simulators soon became the essential component of testing that they are today. The flexibility of reprogramming a simulator was further strengthened with the development of interchangeable cabs, the structures that recreate the cockpit environment. That flexibility allows testing not just of existing aircraft and spacecraft, but any theoretical design for future use. Whether testing a craft for flight on Earth or on another world, the Vertical Motion Simulator, the world's largest, carries on this legacy today.



The Vertical Motion Simulator plays a vital role in the advancement of aerospace vehicle design, development, and training.

AC97-0375-3

1997

Image credit: NASA/Dominic Hart

An early flight simulator set up for pitch and roll motion.⁷

A-26446

1960

Image credit: NASA



11. Simulation Software

Not all simulators shake, rattle, or roll. Following early simulator work, Ames extended its simulation ingenuity and developed the Apollo Midcourse Guidance and Navigation simulator. Astronauts trained in that simulator and tested various course corrections to ensure a safe trip to and from the Moon. As part of that effort, Ames also refined the mathematical techniques that the Apollo Guidance Computer used to determine the capsule's position with more precision. In the skies more directly overhead, Ames has led the development of air traffic management techniques and tools for decades. Today, as the Federal Aviation Administration leads the effort to modernize our air transportation system, Ames researchers continue to develop the automation software tools that the FAA uses to the direct benefit of the flying public.



FutureFlight Central simulator interior, configured to recreate the Los Angeles International Airport tower.

ACD02-0050-2

2002

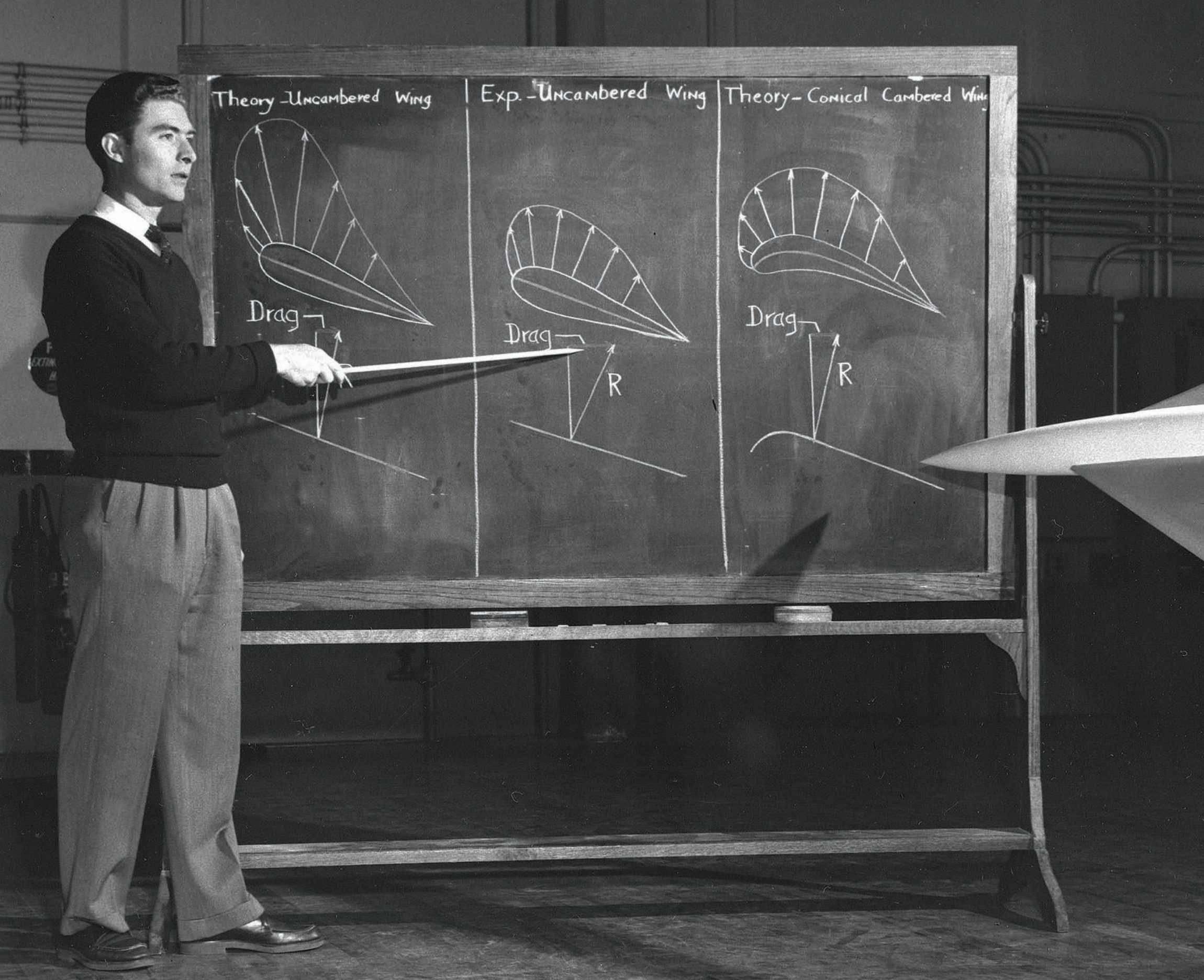
Image credit: NASA/Dominic Hart

NASA Astronauts Mike Collins and Jim Lovell at Ames for training activities in the Apollo Midcourse Guidance and Navigation Simulator.

A-35754

1965

Image credit: NASA/Lampkin



12. NASA in Silicon Valley

As the nascent Silicon Valley grew up around the center, Ames initially kept pace with acquiring and leveraging the latest in computer technology. Advances in computing supported the demanding computations involved in aeronautics research, in addition to spaceflight applications. In the 1940s, slide rules and electric calculating machines were followed by early electronic computers. By the late 1950s, transistors were already replacing vacuum tubes. And while the Apollo Guidance Computer was integral to the development of the integrated circuit, by the time of Apollo 7, the pace of development – think of Moore's Law – made the Apollo Guidance Computer obsolete.⁸ That irony was compounded at Ames, since the center simply couldn't buy new computers every time one was released. As the Apollo program was winding down and other NASA centers acquired newer computers, Ames had fallen behind. But that lapse was temporary, and Ames' third director took action that set Ames on its path to becoming the preeminent NASA center for supercomputing.



The Electronic Machine Computing Branch was founded at Ames in 1952 in the Theoretical and Applied Research Division. An Ames mathematician, Marcelline "Marcie" Chartz Smith, began her career as a computer and later became branch chief.

A-39732

1967

Image credit: NASA/Emerson Shaw

John W. "Jack" Boyd explains the efficiencies of conical camber, a specific type of wing curvature that increased the range of early supersonic planes.⁹ Jack began his service at Ames in 1947 and retired 73 years later, on the day before his 95th birthday.

A-22498

1957

Image credit: NACA



13. Supercomputing

When Hans Mark arrived in 1969, theoretical work in fluid flow was advancing in spite of Ames having been temporarily surpassed by other NASA centers in computing. Before joining Ames, Mark led the Experimental Physics Division at nearby Lawrence Livermore National Laboratory. During his time there, he witnessed great leaps in computing capability. At the same time, Dean Chapman took over the division at Ames where the theoretical work had been progressing, and he and Mark agreed that the state-of-the-art in computing had reached a point that could profoundly impact fluid mechanics work. Chapman created the Computational Fluid Dynamics Branch, and Mark got creative in procuring a new computer when he learned that an IBM 360-67 system supporting the Air Force's Manned Orbiting Laboratory program from neighboring Sunnyvale would soon become surplus. He sent Ames people with a truck to the Air Force installation on the day the program shut down. They brought it back and quickly installed it. That computer jumpstarted the new Computational Fluid Dynamics Branch and through the early 1970s, Ames took advantage of other government computers about to be declared surplus. By 1976, the center was poised to solidify its position within NASA as the place for supercomputing.¹⁰

The Illiac IV was a key component of the development of one of NASA's most significant contributions in the aerospace field: computational fluid dynamics, or CFD. Initially designed and originally intended to be placed at the University of Illinois as an Advanced Research Projects Agency, or ARPA, research facility, ARPA worried that student unrest during the late 1960s could jeopardize the project. Mark persuaded ARPA to place the Illiac at Ames. It arrived in 1972.¹¹

AC72-4296

1972

Image credit: NASA/Lee Jones

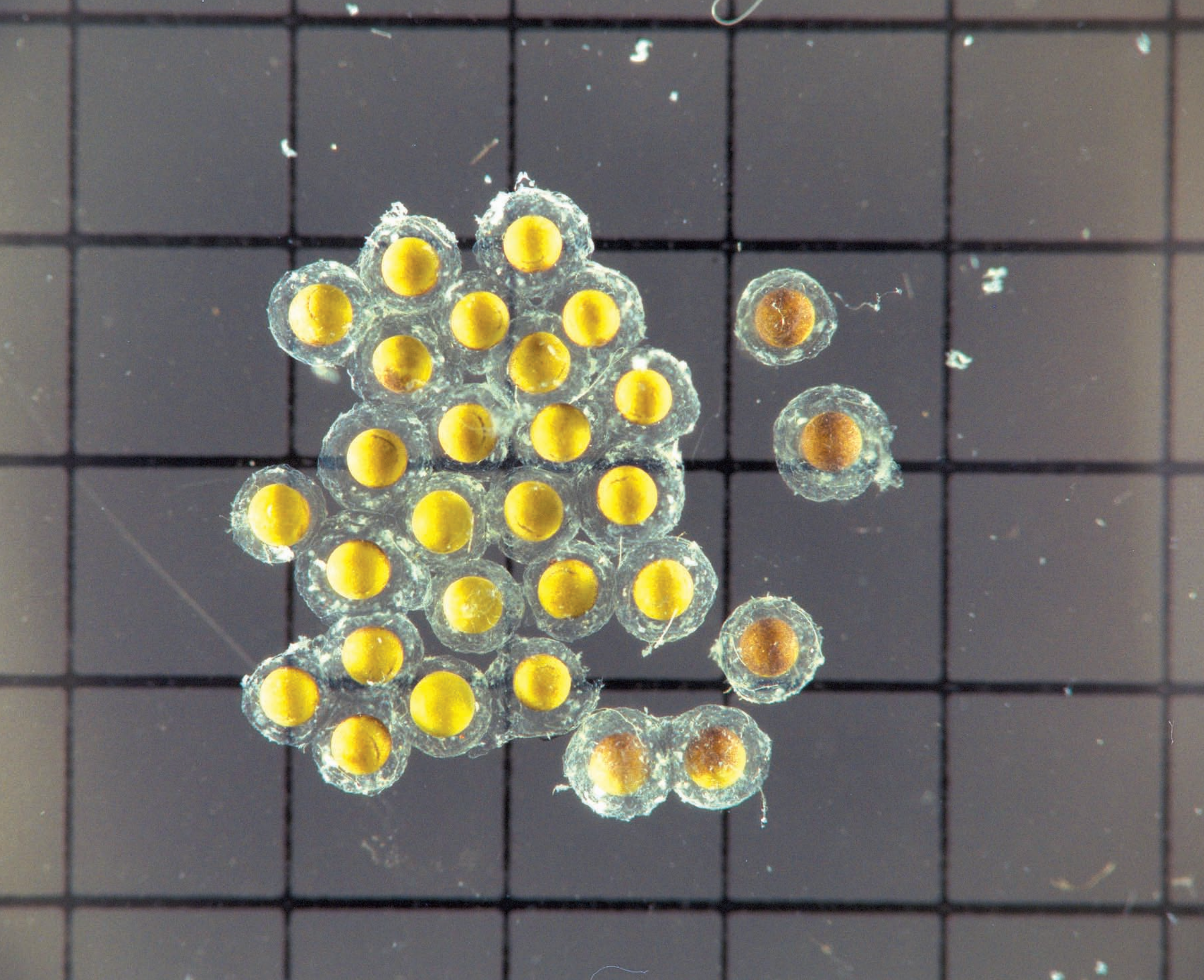


The D-Wave quantum computer in the NASA Advanced Supercomputing Facility at Ames. Ames continues to make advances in supercomputing in Silicon Valley. In addition to pursuing cutting-edge work in quantum computing, Ames also recently opened the Modular Supercomputing Facility, which answers the growing demand for more computing resources while drastically reducing the energy consumption and amount of water required for cooling.

ACD15-0219-069

2015

Image credit: NASA/Dominic Hart



14. Life Sciences Arrive at Ames

Almost as soon as NASA was founded, the agency began developing plans for the life sciences. Those early years were programmatically tumultuous. Ames' first center director, Smith DeFrance, actively courted the NASA Administrator for Ames to host the facility to support life sciences research. Newly formed Goddard Space Flight Center as well as the National Institutes of Health were early favorites for the award, but DeFrance prevailed. It was new programmatic territory. Ames made changes to its organizational structure, including the establishment of the Exobiology Division, the Biotechnology Division, and the Environmental Biology Division, all within the new Life Sciences Directorate. This would both shape the character of Ames we know today and have a lasting impact on the study of earthly life in space. With the Life Sciences Directorate established on paper, the arrival of research biologists within this new directorate (but not yet with a building and equipment) marked a significant milestone in the evolution of the center.¹²



Harold Klein led the Life Sciences Directorate at Ames for two decades.

A-36565

1966

Image credit: NASA/Emerson Shaw

Frog eggs from a Spacelab-J mission experiment that flew aboard space shuttle Endeavour. Ames inaugurated the first NASA fundamental space biology experiment when sea urchin eggs were flown on Gemini III and will continue its decades of life sciences flight experiments when BioSentinel carries yeast into a heliocentric orbit from the Space Launch System rocket that will deliver Artemis I into deep space.

AC92-0552-258

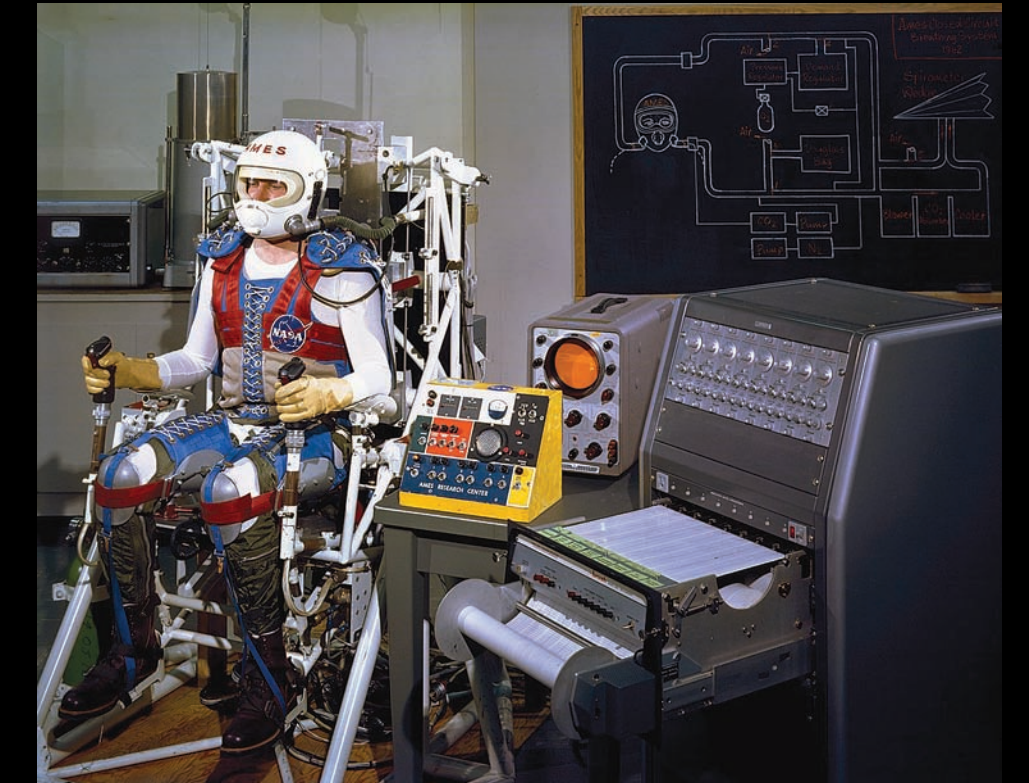
1992

Image credit: NASA/Tom Trower



15. Life in Extreme Environments

Like the NACA researchers before them, the life scientists arriving at Ames prized basic research. What set them apart from the aerodynamicists was a more academic culture that they prized and fought for. Harold Klein had even threatened Smith DeFrance with resigning if a library was not included when the new life sciences building was developed.¹³ Those differences proved beneficial, reinforcing the Ames culture of inquisitiveness and an openness to new ideas. Meanwhile, Ames simulation expertise and use of centrifuges allowed the research to expand into studying life under a variety of gravitational environments. Ames researchers have since extended fundamental life science studies to the microgravity laboratory of the International Space Station and out into deep space, expanding our knowledge and preparing us for long duration human spaceflight beyond Earth orbit.



A pilot test subject wears a respiratory restraint suit during a study of breathing problems encountered during reentry.

AC-30133

1962

Image credit: NASA/Dave West

Vance Oyama controls a life sciences experiment in the Ames 50-foot centrifuge.

A-41652

1968

Image credit: NASA/Emerson Shaw



16. Astrobiology

From exobiology to astrobiology, Ames has led NASA in the study of the origins, evolution, and distribution of life in the universe. Astrobiology is a cornerstone of our continuing motivation to explore the solar system, and its development at Ames is a story about the ability to adapt. NASA faced significant budget cuts in the early 1990s, and more were expected. As part of that process, a Zero Base Review (i.e., drafting a budget starting at zero as opposed to formulating a budget based on a previous year) was initiated in an attempt to streamline NASA without losing its aerospace preeminence. This was a tense time for the agency and especially Ames, which faced the very real threat of closure. This moment of crisis galvanized the Ames community and allies in the San Francisco Bay Area and at NASA Headquarters. In addition to “astrobiology,” a term that NASA first officially printed in its 1996 Strategic Plan, Ames emerged from the upheaval as NASA’s recognized leader in not just astrobiology, but information technology and aviation system safety as well.¹⁴ Ames had the interdisciplinary strength for decades, and interdisciplinary strength remains a hallmark of astrobiology.



The Atacama Rover Astrobiology Drilling Studies on deployment in Chile’s Atacama Desert.

nasa.gov/feature/ames/arads-drill

2019

Image credit: NASA/Campoalto/Victor Robles

This illustration from the Ames exobiology program depicts cosmic evolution. Time progresses to the right, beginning with the formation of stars and planets, followed by primitive life becoming complex, culminating in the present.

AC88-0741

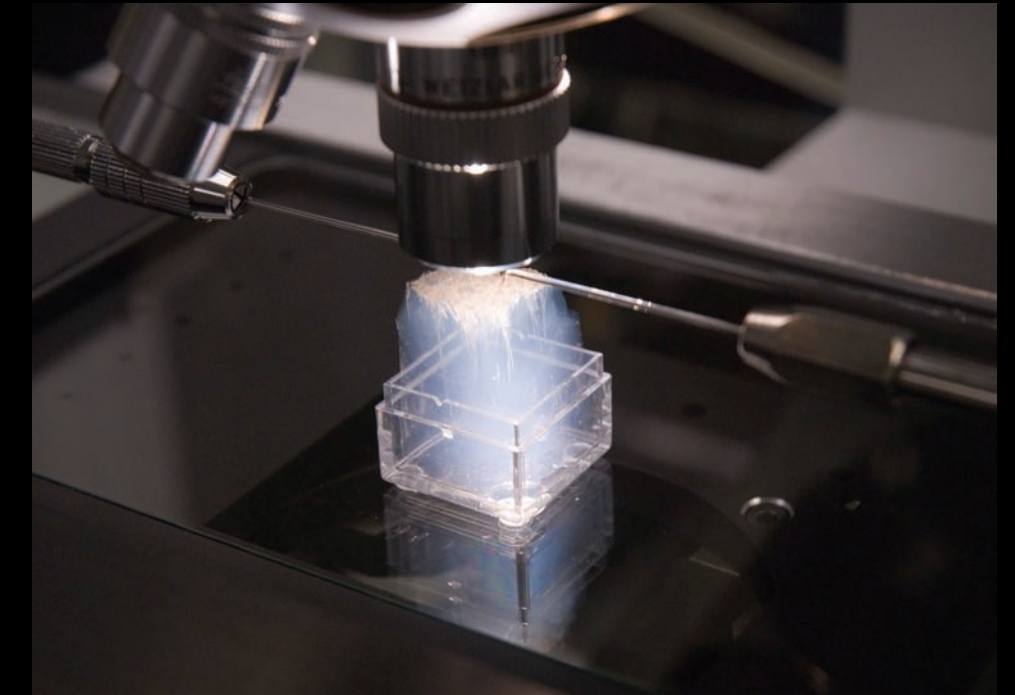
1988

Image credit: NASA/Robert Bausch



17. Cosmic Origins

Ames researchers have been instrumental in safely returning and studying samples from deep space. One example, the Stardust mission, returned cometary particles and interstellar dust grains that have helped unlock clues to the origins of our solar system. Ames researchers devised methods to improve the collection of the particles in a special material known as aerogel. Drawing upon its strength in reentry technology, Ames developed the heatshield that protected the Stardust capsule for its return to Earth. Ames also studied the chemical interactions of the heatshield material during reentry to draw connections to meteor observations, helping us understand their composition as they interact with the atmosphere. From studying the primordial conditions on Earth to the continuing work today in re-creating astrophysical conditions in the lab, these multidisciplinary efforts drive the interplay between observation and experimental data, leading to new mission concepts and the development of new technologies and instrumentation.



A Stardust aerogel sample ready for analysis in a clean room at the Space Sciences Laboratory at the University of California, Berkeley.

ACD06-0216-016

2006

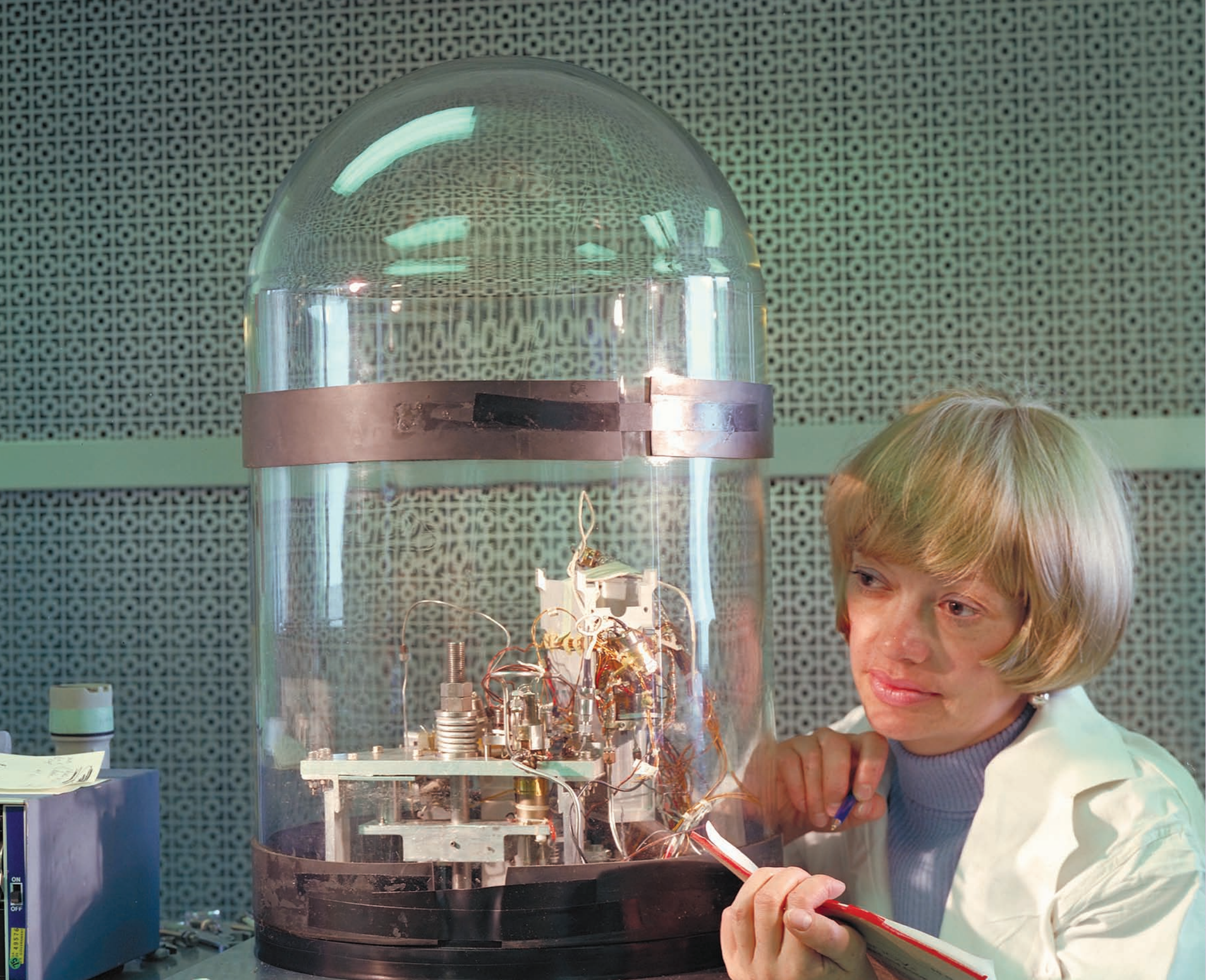
Image credit: NASA/Eric James

In the pre-astrobiology days of exobiology, Cyril Ponnampерума of the Ames Biochemical Evolution Branch works with the electrical-discharge apparatus used in his experiments on the chemical origins of life.

AC-33753-7

1964

Image credit: NASA/Emerson Shaw



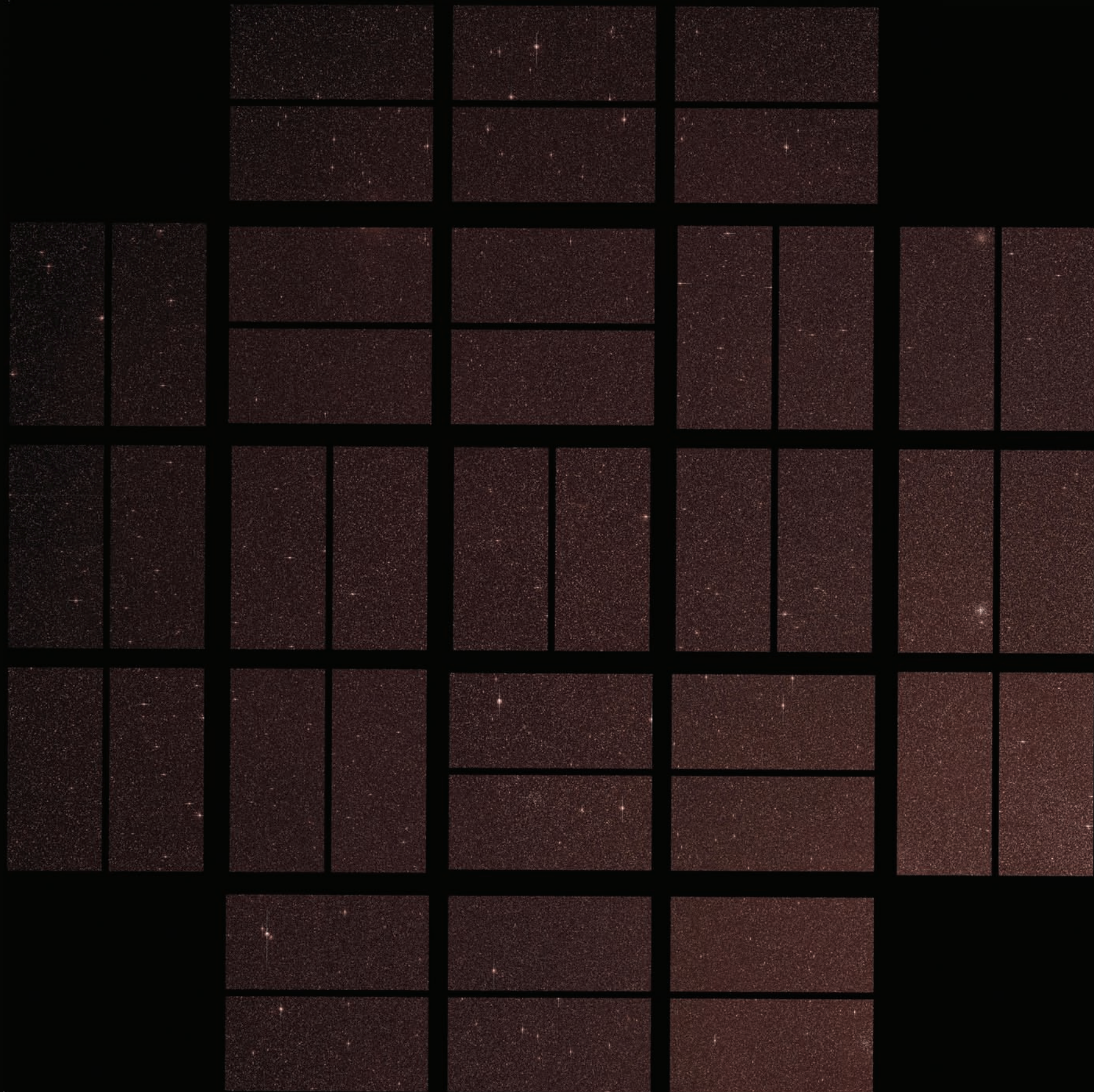
18. Searching for Signs of Life

Ames was an early leader in studying life in extreme environments and searching for life beyond Earth. Ames researchers were among the first to inspect lunar samples and check for signs of life when Apollo 11 returned from the Moon. A few years later, Harold Klein led the biology team for NASA's Viking mission that successfully landed on Mars and returned a wealth of chemical data from the surface of the Red Planet. While the results of Viking could not confirm any signs of life, the life sciences at Ames expanded beyond exobiology and gravitational biology, encompassing biomedical research, ecosystem science and technology, and advanced life support systems. With the NASA Astrobiology Institute, Ames led the development of virtual institutes for NASA for two decades, leveraging the most effective information and communications technology to enable collaborative and interdisciplinary research across institutional and geographic boundaries. This shaped and strengthened the scientific community as the new interdisciplinary field of astrobiology came into its own.

Bacteriologist Bonnie Dalton with a test module for the Viking biological experiments.
 AC76-0564
 1976
 Image credit: NASA/Richard Clayton



Biologist Elaine Muñoz transfers an Apollo 11 lunar sample in the glove box in the Lunar Biological Laboratory.
 A-42500-127
 1969
 Image credit: NASA/Harry Zabower



19. More Planets than Stars

Beyond our own solar system, astronomers discovered the first exoplanet in orbit around a Sun-like star in 1995. A year later, the project proposal that would become the Kepler space telescope faced its third rejection. The Kepler mission is, in many ways, a story of determination.

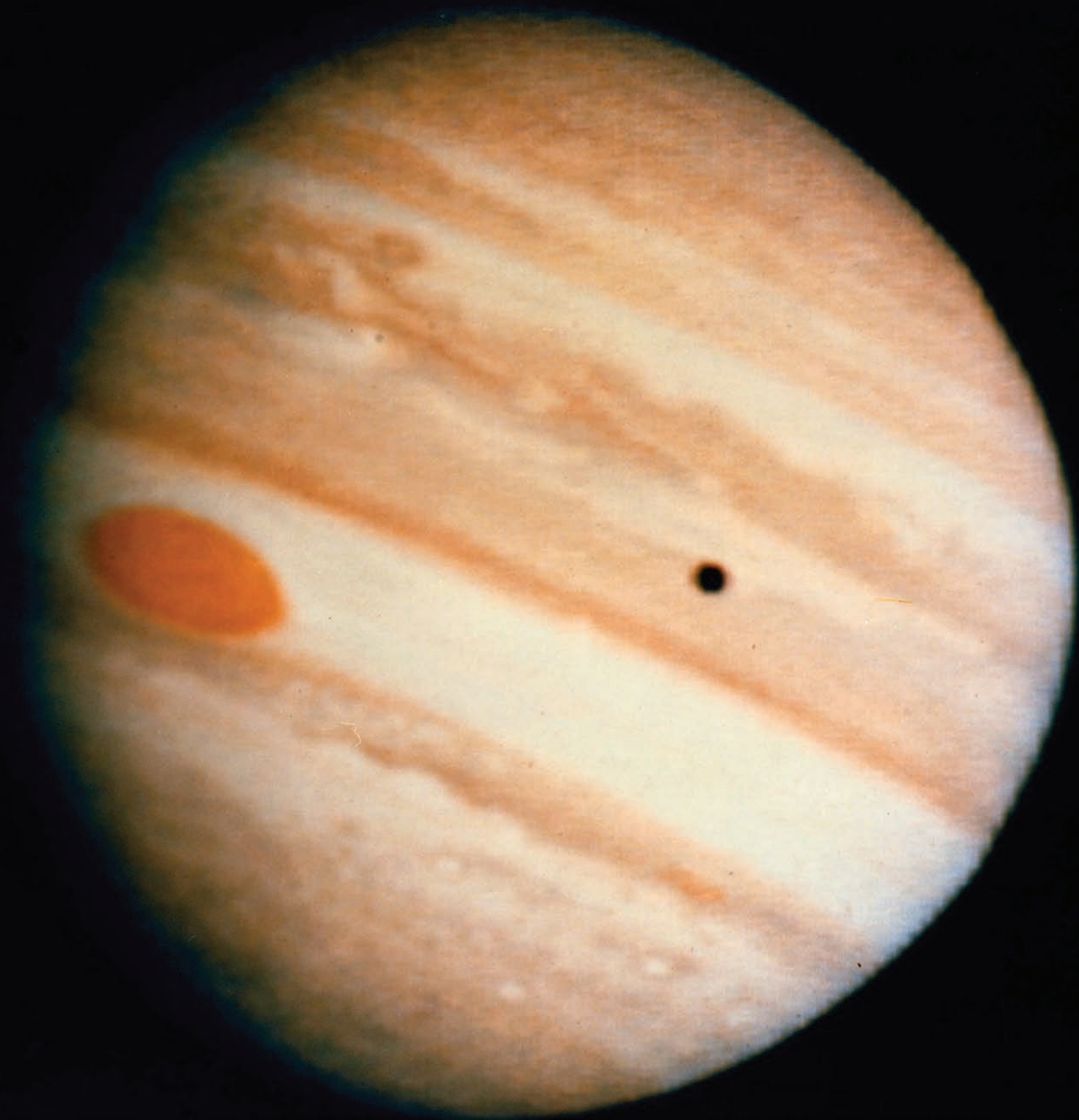
Ames' Bill Borucki had first proposed using photometric transit to detect exoplanets in 1984. After the 1996 rejection, an Ames team designed and built the Vulcan camera to demonstrate the technology, which was installed at the Lick Observatory near San Jose, California. The testing showed that the continuous, automatic monitoring of 100,000 stars was possible. A fourth rejection followed. A team then built a simulated, 1,600-star sky in the Ames photometry laboratory that proved the precision and noise control that they had achieved would enable success. That sealed it, and the project became NASA's tenth Discovery-class mission.¹⁵

Kepler launched in 2009, becoming NASA's first mission that could find Earth-size planets within the habitable zones of other stars. At the time, a few hundred exoplanets had been confirmed. Kepler would discover more than 2,600 worlds before the spacecraft was retired in late 2018. From the data Kepler returned, there are still more than 3,000 candidates that could be confirmed as the science and the search that the mission enabled continues.¹⁶ The number of stars in the Milky Way is vast. Kepler showed us that there are more planets than stars in our galaxy.



A tabletop model of the Kepler space telescope.
ACD06-0131-011
2006
Image credit: NASA/Tom Trower

"First light" from the Kepler telescope's field of view.
PIA11984
2009
Image credit: NASA/Jon Jenkins



20. Pioneers

Throughout its history, Ames has led missions that generated tremendous scientific return for modest investment. The Pioneer missions exemplify this spirit. In the 1960s, Pioneers 6 through 9 were managed at Ames and became the first space-based solar weather-monitoring network, measuring solar wind, cosmic rays, magnetic fields, and cosmic dust. Ames continued the program with Pioneers 10 and 11, which became the first two of only five spacecraft that have been sent on trajectories that will carry them out of the solar system.

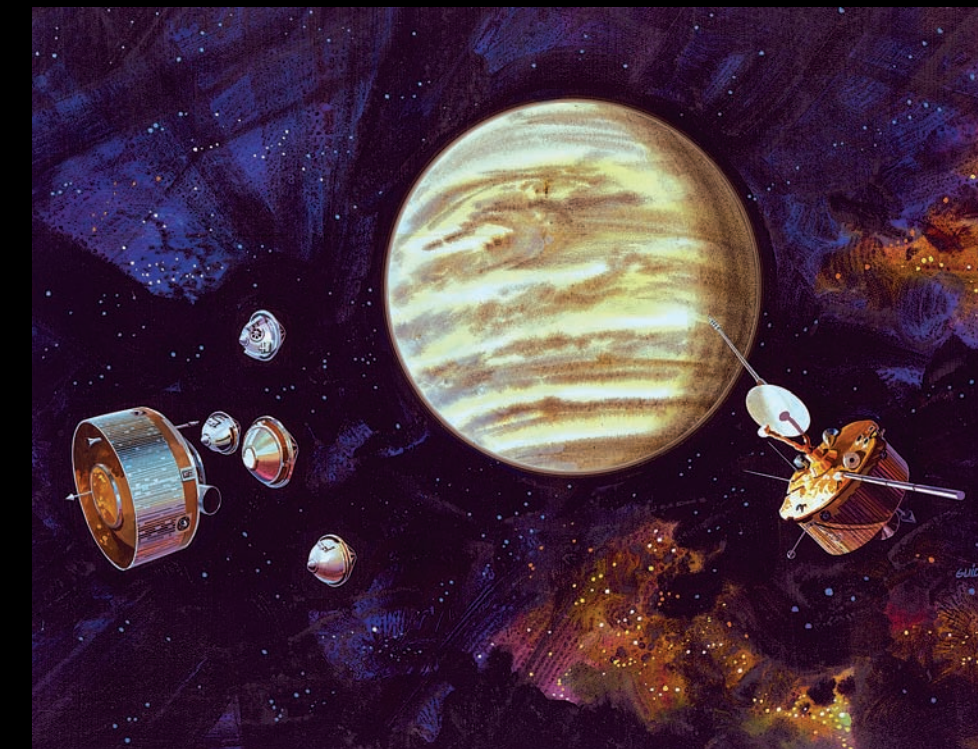
Following Pioneer 11, the Pioneer Venus mission sent an orbiter and a separate craft that deployed four probes to different locations on Venus. As the probes entered the Venusian atmosphere, they returned comprehensive data and even information about the surface of the planet, as one of the probes steadfastly survived for about an hour after impact. Ames planetary scientists, equipped with new data about Venus, refined their models of the planet's atmosphere, which advanced our understanding of the greenhouse effect on Earth. Following in the footsteps of missions like Pioneer Venus, Magellan, and the Soviet Venera probes, NASA is returning to Venus with the Discovery Program missions DAVINCI+ and VERITAS, and the European Space Agency's EnVision.

The first spacecraft to travel beyond the asteroid belt and take close-up pictures of Jupiter, Pioneer 10 captured this image of the Great Red Spot and a shadow of the moon Io, before continuing on its journey out of our solar system.

AC73-9175

1973

Image credit: NASA



An illustration of the Pioneer Venus orbiter and its atmosphere entry probes.

AC78-0238-1

1978

Image credit: NASA/Rick Guidice



21. Airborne Science

Whether gazing up at the cosmos or peering down at Earth, airborne science platforms have provided decades of timely and cutting-edge research. In Earth sciences, Ames aircraft have mapped croplands and soils to support agriculture, while studying how land interacts with the atmosphere.¹⁷ Ames-developed sensors also have imaged and mapped wildfires in real-time from the air, sending the data over the internet for firefighters on the ground.¹⁸ In NASA aircraft and high-altitude balloons, the Ames Aerobiology Lab studies microbes in extreme environments.

In infrared astronomy, Ames continues to make contributions that have spanned decades. Before the Pioneer Venus mission entered the planet's atmosphere, Ames researchers conducted infrared airborne observations aboard a Learjet in 1972 that detected sulfuric acid in high concentrations. Building upon the success of the Learjet as a platform for infrared astronomy, the Kuiper Airborne Observatory operated from 1974 through 1995, discovering the rings of Uranus, detecting the atmosphere on Pluto, and contributing to our understanding of star formation. Translating this airborne infrared expertise to spacecraft, Ames designed the telescope for the Infrared Astronomical Satellite that conducted the first whole-sky infrared survey.¹⁹

California's Golden Gate to the Sierra Nevada in infrared, imaged by an Ames U-2 aircraft.
ACC 00281-107
1972
Image credit: NASA



An illustration of the rings of Uranus, discovered by the Kuiper Airborne Observatory.
AC77-1069
1977
Image credit: NASA/Rick Guidice



22. SOFIA

Today, NASA's Stratospheric Observatory for Infrared Astronomy, or SOFIA, continues the legacy of the Kuiper Airborne Observatory, in partnership with the German Aerospace Center, or DLR. In a modified Boeing 747SP, SOFIA, the world's largest airborne observatory, carries a telescope with about eight times as much area as the KAO's, and flies above the vast majority of water vapor in the atmosphere that otherwise obscures infrared observations.

SOFIA's versatility remains unmatched. Unlike ground-based observatories, SOFIA is capable of flying across the globe, opening up observations of the night sky from almost anywhere in the world. And unlike space-based observatories, SOFIA can have its instruments routinely serviced, upgraded, and exchanged, allowing it to adapt over time and serve as a testbed for future space-based technology.

As Ames researchers have studied the chemistry of our cosmic origins, SOFIA complements those laboratory investigations with astronomical discoveries. SOFIA helps scientists study many different phenomena, from the formation of stars to black holes and the origin of Earth's oceans. For the first time seen in space, SOFIA recently detected a modern version of the universe's first molecule, helium hydride, and discovered water on the sunlit surface of the Moon.

SOFIA soars over the Sierra Nevada with its telescope door open during a test flight.

nasa.gov/sites/default/files/thumbnails/image/sofiaoversierra.jpg

2010s

Image credit: NASA/Jim Ross

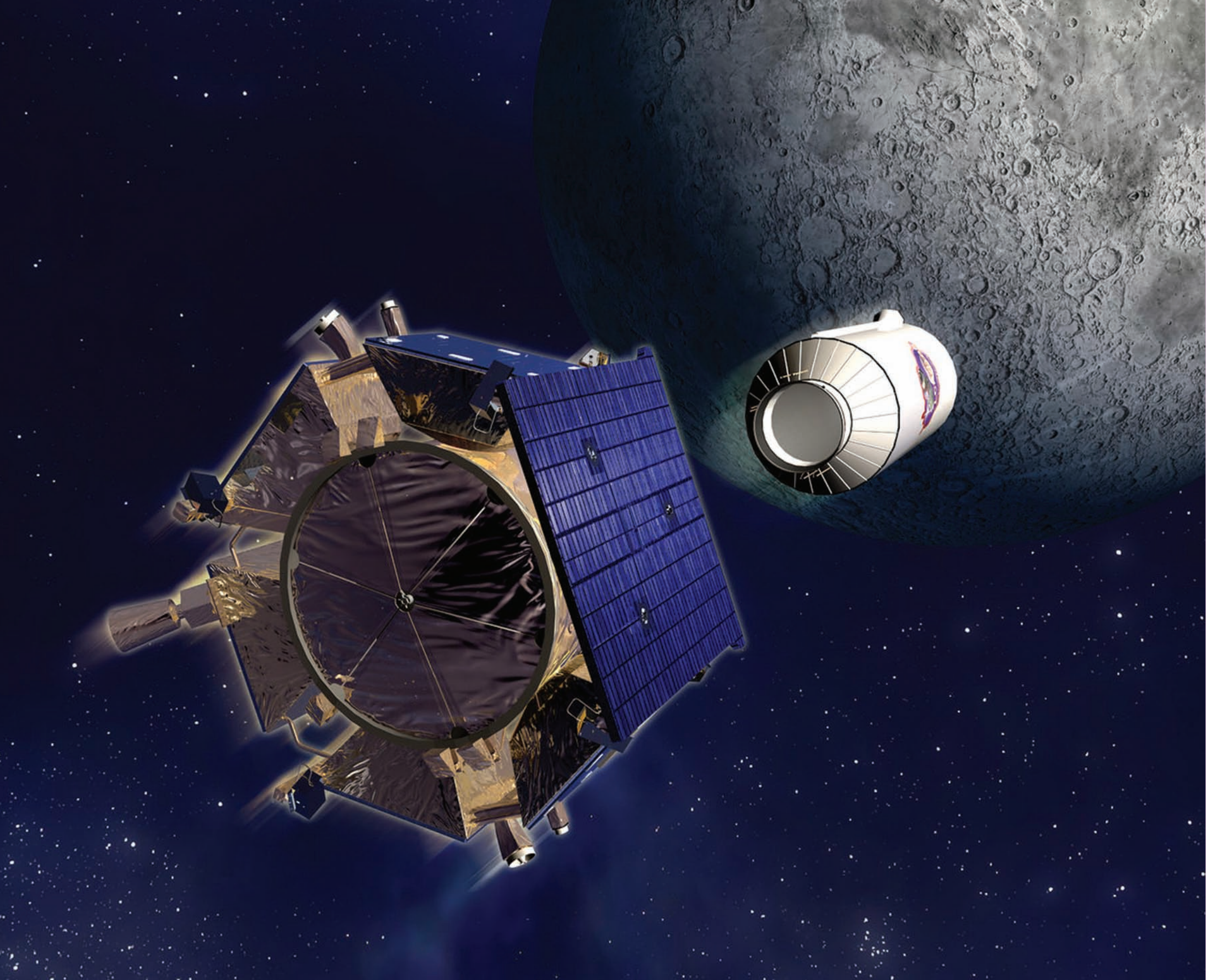


SOFIA studied this galaxy, NGC 1086, using far-infrared light to reveal facets of its magnetic fields that previous observations using visible and radio telescopes could not detect. This composite image relies upon SOFIA, the Hubble Space Telescope, the Nuclear Spectroscopic Array and the Sloan Digital Sky Survey.

nasa.gov/feature/how-to-shape-a-spiral-galaxy

2019

Image credit: NASA/SOFIA/JPL-Caltech/Roma Tre University



23. Water on the Moon

Since before humans landed on the Moon, Ames researchers have been contributing to our understanding of our nearest celestial neighbor. On the physics side, our facilities enabled investigations into how craters form, and, on the biology and chemistry side, Ames researchers studied the Apollo 11 samples and confirmed the notion that the Moon was barren. For decades, there was no evidence to suggest that there could be water on the Moon. That changed in the 1990s when the Clementine mission found faint hints of what could be water ice on the Moon. To investigate further, Ames led the Lunar Prospector mission and found high hydrogen levels at the poles that strongly suggested water ice. At the end of the mission, Lunar Prospector was directed to crash into the South Pole of the Moon so that telescopes observing the impact might have a chance to detect signs of water vapor, but the signal was too faint. If only a sensor could have flown through the plume that was kicked up.

The Lunar Crater Observation and Sensing Satellite, or LCROSS, did exactly that in 2009. The confirmation of water ice – and lots of it – on the South Pole changed our perception of what is possible on the Moon. Missions to refine our understanding followed. With LADEE, the Lunar Atmosphere and Dust Environment Explorer, Ames invented a new spacecraft architecture. The instruments aboard LADEE probed the extremely tenuous atmosphere of the Moon and enabled further study of the mechanisms responsible for its creation, including how water gets there. NASA will sample and map that water directly with a new rover, the Volatiles Investigating Polar Exploration Rover, or VIPER, continuing our exploration into the 2020s.



A data visualization showing the Nobile region at the lunar South Pole. The terrain in the Nobile region is most suitable for the VIPER rover to navigate, communicate, and characterize potential water and other resources.

svs.gsfc.nasa.gov/4937

2021

Image credit: NASA's Scientific Visualization Studio

An illustration of the Lunar Crater Observation and Sensing Satellite, or LCROSS, spacecraft and Atlas V Centaur upper stage rocket separation.

[ACD06-0232-010](#)

2006

Image credit: NASA



24. Synthesis Across Boundaries

From its roots as an aeronautical laboratory of the NACA to a research center within NASA, Ames has inherited a rich past that continues to inform the future. The interplay between research efforts, and the creativity, diversity, and dedication of the people of Ames keep it vital. No single image, project, or milestone can capture the essence and depth of Ames and its contributions. The images within this book speak to the interconnected legacies of Ames and the purposeful integration of the fields of research that Ames advances. Ames remains open to testing new ideas and maintaining the kind of inquisitiveness and excellence that ensures we can meet our current challenges with skill and face future ones with confidence.



Jing Li inspects sensor array chips inside the NASA E-Nose, or electronic nose, for detecting coronavirus disease.

ACD20-0073-031

2020

Image credit: NASA/Dominic Hart

During a first-of-its-kind demonstration, data from a wind tunnel test of the Space Launch System rocket was sent directly to the NASA Advanced Supercomputing facility for real-time visualization of the results. Ames aerospace engineer Nettie Roozeboom, right, discusses the preliminary data with aerodynamics engineer Thomas Steva, left, of NASA's Marshall Space Flight Center.

ACD19-0157-026

2019

Image credit: NASA/Dominic Hart



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End Notes

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⁴Muenger, 143-155.

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⁶Hartman, 197.

⁷Ibid., 290 & 340.

⁸Ceruzzi, Paul. "Apollo Guidance Computer and the First Silicon Chips," October 14, 2015. <https://airandspace.si.edu/stories/editorial/apollo-guidance-computer-and-first-silicon-chips>.

⁹Hartman, 247.

¹⁰Muenger, 173-174.

¹¹Ibid., 176.

¹²Ibid., 92-97.

¹³Ibid, 103.

¹⁴Bugos, 2014, 27-30.

¹⁵Ibid., 86-92.

¹⁶https://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html

¹⁷Bugos, 2014, 127.

¹⁸Ibid., 130.

¹⁹Ibid., 82.

The Ames hyperwall in the NASA Advanced Supercomputing facility. From aerodynamics to earth system science, supercomputing enables the insights that inform our decisions.
ACD08-0147-033
2008
Image credit: NASA/Dominic Hart

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In memory of Lynn Albaugh and Danielle Carmichael. Always include the Ames "A" numbers when using photos for Lynn, and share your NASA stories far and wide for Danielle.

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