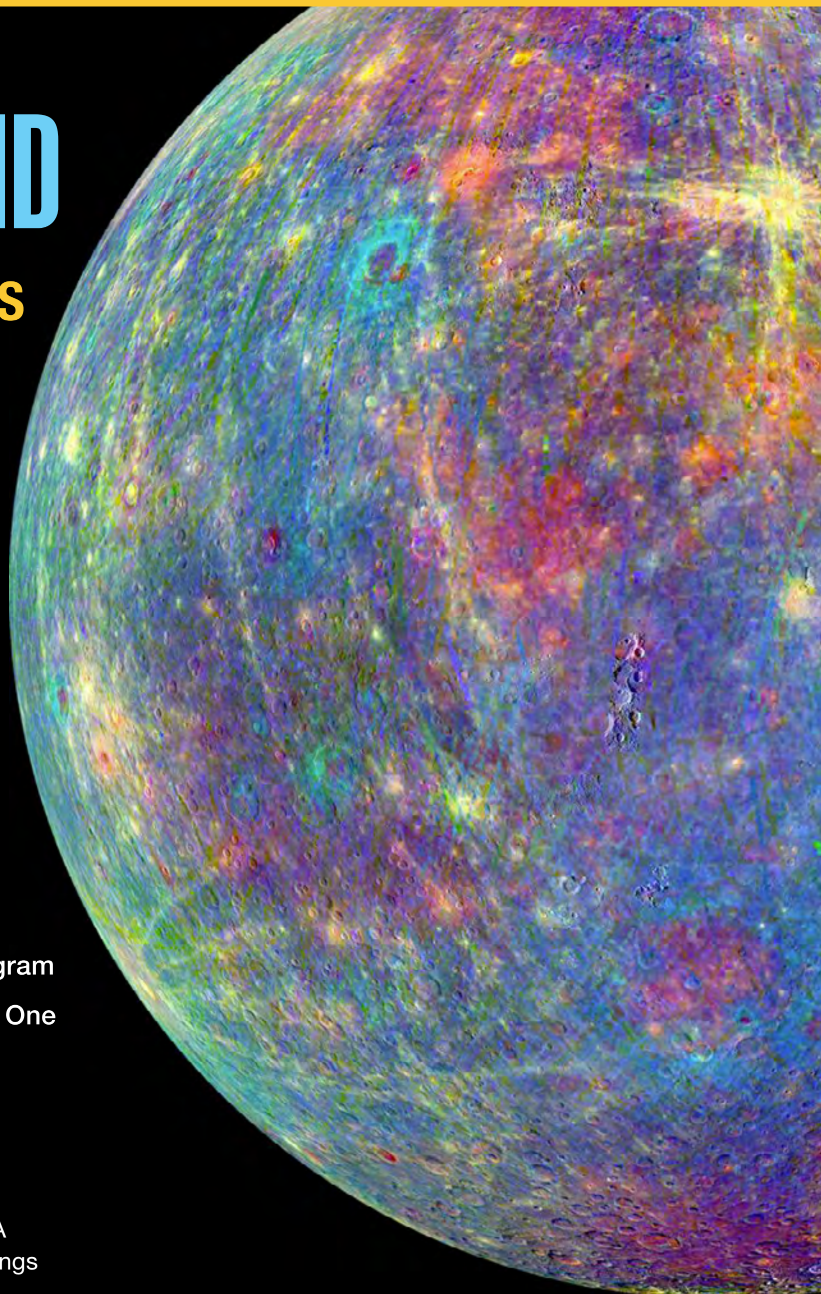
National Aeronautics and
Space Administration

NASA HISTORY
NEWS & NOTES

Volume 40, Number 3 Fall 2023



WORLDS BEYOND

ILLUMINATING THE MYSTERIES OF OUR SOLAR SYSTEM

↗ Data acquired from NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft showing the composition of Mercury's surface rock is overlain on a monochrome global mosaic. (Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington)

NASA HISTORY OFFICE
OFFICE OF COMMUNICATIONS

From the Chief Historian

NASA's Juno spacecraft captured this hypnotic image of Jupiter's northern hemisphere on 29 May 2019. (Image credit: NASA/JPL-Caltech/SwRI/MSSS/Kevin M. Gill)

IT HAS BEEN A BUSY YEAR for NASA's Planetary Science program. Scientific data continue to return from Mars, the Moon, and beyond. The historic Parker Solar Probe mission, launched in August 2018, continues its work revolutionizing our understanding of the Sun and solar radiation. This fall, the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) mission, part of NASA's New Frontiers Program, will deliver to Earth a sample collected in 2020 from the asteroid Bennu. With an eye toward producing a better understanding of how the early solar system formed, OSIRIS-REx will not only shed light on how life began, but it will also add to our ability to understand how asteroids might impact life on Earth in the future. Soon, the most recent of NASA's Discovery Missions, Psyche, will launch to an asteroid of the same name with a goal of exploring the object's metallic core.

The OSIRIS-REx and Psyche missions are indicative of the dynamic work taking place over the last three decades as part of NASA's Discovery and New Frontiers Programs—key programs in the overall Agency planetary science portfolio. Several other significant projects are coming soon to the programs, including Megane (September 2024); Dragonfly (2026); Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) (projected for 2028–30); and Veritas (2028–30).

Formed under the paradigm of "faster, better, cheaper," both programs were designed from the premise that planetary science could be accomplished with innovative and efficient approaches to project management. Principal investigators (PIs) from research institutes or academic institutions propose competitive missions and build teams across government, industry, and academia to accomplish specific scientific goals.

As with "faster, better, cheaper," the goals are to utilize breakthrough technologies and strong teams to keep costs down and schedules predictable. While everyone understands that the old version of "faster, better, cheaper" suffered from a fundamental flaw—the adage "you can have two, but not all three" comes to mind—many of the core successes in planetary science over the past three decades have come from these programs. Deep Impact's rendezvous with a comet; Kepler's search for exoplanets; MErcury Surface, Space ENvironment, GEochemistry, and Ranging's (MESSENGER's) encounter

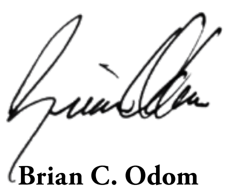
> ...many of the core successes in planetary science over the past three decades have come from these programs.

with Mercury; Juno's mission to Jupiter; and New Horizons' trip to Pluto (poor Pluto) are just a handful of noteworthy efforts.

But the question we keep coming back to is this: How do these programs differ from the "golden age" of planetary science in the 1970s—which included Mariner, Viking, and Voyager missions—and the numerous other, larger programs since, such as Ulysses, Galileo, and Cassini? Does it simply come down to budget and schedule, or is there something more significant at play? Beyond this, what role has international collaboration occupied in this process? Are the programs properly positioned to execute the goals delineated by the National Academy of Sciences' recent publication **"Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032"**?

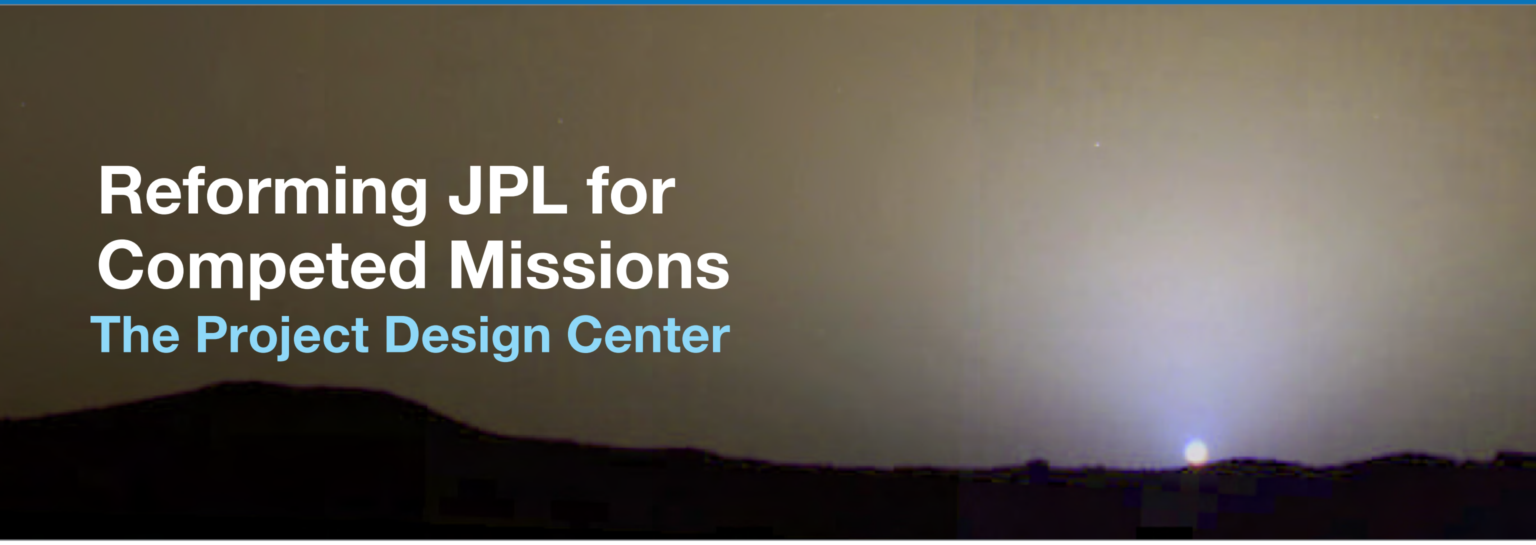
In January 2024, the NASA History Office, in collaboration with the National Academy of Sciences and the Smithsonian's National Air and Space Museum, is hosting a symposium at the National Academy of Sciences in Washington, DC, to explore the history of these two NASA programs at the 30th anniversary of Discovery and the 20th anniversary of New Frontiers. Our goal is to recognize key historic milestones while also gaining an understanding of the overall impact of the missions on planetary science, their effect on society, how the approach has changed over time, and where the programs stand at present.

To provide some historical context for the upcoming event, we are dedicating this issue of *News & Notes* to the theme of planetary science. These articles cover important topics, including the reformation of the Jet Propulsion Laboratory's (JPL's) approach to planetary science in the 1990s, NASA's collaboration with the Department of Defense on the Clementine mission, the work of artist Les Bossinas at NASA's Glenn Research Center, the hunting of exoplanets, the testing of hardware for the space environment, and a comparative look at international planetary science. Also included in the issue are highlights from critical archival collections on MESSENGER and the Mars Observer. An interview with Goddard Chief Scientist and DAVINCI PI Dr. James Garvin offers a unique perspective of planetary science from one of its chief practitioners. Personally, I can't wait to see where we are in planetary science in the decades to come. ■



Brian C. Odom
Chief Historian

↓ NASA's OSIRIS-REx became the first U.S. mission to collect a sample from an asteroid on 20 October 2020, and it will return to Earth on 24 September 2023 with material from asteroid Bennu. (Image credit: NASA/GSFC/University of Arizona)



Reforming JPL for Competed Missions
The Project Design Center

↑ This four-frame true-color mosaic of a Martian sunset was taken by Mars Pathfinder on sol 24 of its mission in July 1997. (Image credit: NASA/JPL)

» By **Erik M. Conway**, Historian, Jet Propulsion Laboratory

THE END OF THE COLD WAR produced a substantial change in NASA's budgetary standing. Outrun budgets projecting growth throughout the 1990s became projections showing shrinkage. From a fiscal year (FY) 1991 peak of $18.8 billion (in 2005 dollars), NASA shrank to $15.1 billion in FY 2000.[1] NASA's Discovery program came out of this era of diminishment, and its model of competition spread to the Agency's other robotic mission areas.[2]

Cost was not the only driver behind the new model. In planetary science, mission rates had gotten so low—perhaps a mission a decade—that there were also demands from the scientific community for more frequent missions. One could not sustain a vibrant research program with so little data at either an individual level or a more collective one.[3]

For the Jet Propulsion Laboratory (JPL), competition was a major challenge. While other NASA facilities had done planetary missions, by 1991 the Laboratory had a near monopoly. It tended to have one "big" mission—what we would now call a flagship mission, like the Galileo Jupiter orbiter—and one or two smaller ones. In 1991, those were flagship Cassini-Huygens, just getting started, and the nearly completed Mars Observer and TOPEX/Poseidon ocean topography missions. These were all assigned by NASA, generally after a lengthy process of formulating scientific objectives via a science definition team, after which NASA chose instruments to fulfill the objectives. Instruments were competed, not missions.

The Discovery Program meant to change that model by having individual scientists formulate and propose missions that were to be scientifically focused and carried out under a cost cap. Proposers did not have to be attached to any NASA Center, enabling new entrants to compete for planetary missions. JPL's planetary business was no longer guaranteed.

Mike Neufeld's history of the Discovery Program focuses on the first two—non-competed—Discovery missions, Near Earth Asteroid Rendezvous (NEAR) and Mars Pathfinder.[4] The Mars Pathfinder story in particular is told in a "skunkworks" vein, in which a small group of "renegades" from the dominant, conservative JPL engineering culture tried a new approach to development.[5]

But in order to effectively compete for future missions, JPL also undertook

Proposers did not have to be attached to any NASA Center, enabling new entrants to compete for planetary missions. JPL's planetary business was no longer guaranteed.

internal reforms. One important change was to the proposal formulation process itself. JPL had typically done 10 to 12 per year, costing $250,000 each. They took, on average, a half year to assemble. They were prepared in pieces, with each of the many technical specialists involved working individually within his or her own disciplinary organization. There was little communication, and costing was done at the end of the process. That meant cost was not really a design factor.

JPL Director Edward C. Stone had launched reform efforts in 1991 with the introduction of Total Quality Management (TQM), and in 1993, he began a "reengineering" drive.[6] Redesign of the proposal procedure took place under the unexcitingly named Develop New Products process. The Lab's Executive Council had called for reengineering "JPL's project and system engineering processes and to provide processes and tools to implement JPL projects in a design-to-cost environment."[7]

E. Kane Casani, who had led a low-cost Defense Department mission called Miniature Seeker Technology Integration (MSTI), advocated for developing new mission proposals through concurrent engineering. He defined concurrent engineering as "the application of classical system engineering in an integrated computer environment." Instead of the dispersed, relatively solitary, and individualized process JPL had traditionally used, a group of engineers drawn from the variety of technical disciplines needed for robotic space missions would work together over a period of a few hours to develop the mission concept. Concurrency was based on the idea that "design is the process of socially constructing a technical reality. It is not the work of individual designers but the interplay of individual work and the relations between the designers."[8] Design, even the design of spacecraft, was better fostered collectively.

The concurrent design group was established within a new Project Design Center (PDC) in April 1995, just a month before the similar concept of Integrated Product Teams became Defense Department policy.[9] The Project Design Center's infrastructure was a set of networked computer workstations that operated a variety of software tools. Some were tools designed within the various technical divisions for other purposes—there was one for assessing radiation doses for Jupiter orbiters, for example. Some were commissioned for it specifically. The "backbone" of the design system was a set of networked spreadsheets JPL had commissioned from Aerospace Corporation that were based upon its cost model.[10] It ensured costing was always a factor in the design effort.

There was some initial concern that the PDC would not have enough business to be viable, but it was quickly dispelled.

There was some initial concern that the PDC would not have enough business to be viable, but it was quickly dispelled. In 1996, the PDC developed 45 proposals at a cost of around $75,000 each. Demand was such that what became known as Team X was duplicated to handle all the proposal work. Each proposal took about two weeks of effort instead of six months.[11]

The PDC's service was not restricted to JPL. Potential mission principal investigators could apply to use it. It also was not restricted to planetary missions. Earth science and astrophysics missions were designed, and even "candidate mission roadmaps" were investigated.[12]

By 2011, Team X had performed 1,045 studies of all kinds. JPL became very successful in Discovery program competitions, winning the Genesis, Deep Impact, Dawn, Gravity Recovery and Interior Laboratory (GRAIL), InSight, and Psyche missions. And while the NASA budget shrank during the 1990s, JPL's business grew slowly as the Lab adapted to NASA's competitive era. Other internal reforms contributed to the ability to manage the rapidly expanding number of projects competition brought, but concurrent engineering within the Project Design Center was key to winning that new business. ■

Endnotes

1. *Aeronautics and Space Report of the President, FY 2006 Activities*, p. 102.
2. Michael J. Neufeld, "Transforming Solar System Exploration: The Origins of the Discovery Program, 1989–1993," *Space Policy* 30, no. 1 (February 2014): 5–12, https://doi.org/10.1016/j.spacepol.2013.10.002 (accessed 23 August 2023).
3. Stephanie A. Roy, "The Origin of the Smaller, Faster, Cheaper Approach in NASA's Solar System Exploration Program," *Space Policy* 14, no. 3 (August 1998): 153–171, https://doi.org/10.1016/S0265-9646(98)00021-6 (accessed 23 August 2023).

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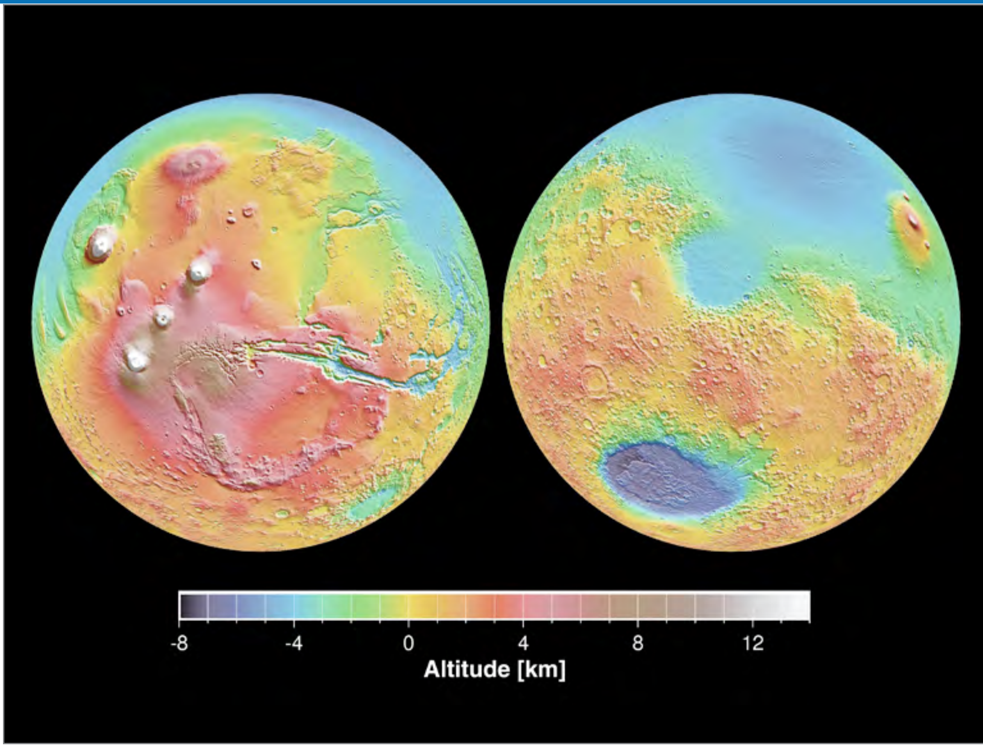
Records from NASA's Mars Laser Altimeter Story Live On

» By **Christine Stevens**, Archivist, Goddard Space Flight Center



These global false-color topographic views of Mars were created from data from the Mars Orbiter Laser Altimeter (MOLA). The left-hand image features the Tharsis topographic rise (in red and white). The right-hand image features the Hellas impact basin (in purple). (Image credit: NASA/JPL/Goddard)

HAVE YOU EVER WONDERED how scientists are able to study Mars's landscape in three dimensions? Well, you can partially thank the MOLA instruments for that! In September 1992, the Mars Observer spacecraft was launched with the Mars Observer Laser Altimeter (MOLA) instrument on board. The primary objective of this instrument was to determine the topography of Mars. Unfortunately, in August 1993, contact with the Mars Observer was lost a few days before Mars orbital insertion, and no data was returned. However, the mission's goal of mapping Mars helped get the next MOLA, this time named the Mars Orbiter Laser Altimeter, off the ground.

The Mars Orbiter Laser Altimeter, also known as MOLA, was on board the Mars Global Surveyor when it launched in November 1996. This MOLA's goal was the same as the previous iteration's: to map the topography of Mars and measure the height of water and carbon dioxide clouds. The way the laser altimeter worked was relatively simple. The laser altimeter transmitted a laser pulse toward Mars's surface, where the pulse was then reflected back to the instrument, where the return was detected. The travel time down and back was recorded, giving a measure of the distance between the spacecraft and the surface. The Mars Global Surveyor successfully reached Mars orbit, and the data returned from the MOLA instrument produced the first global view of the topography of Mars. These detailed elevation maps significantly contributed to our understanding of Mars's geology and climate history.

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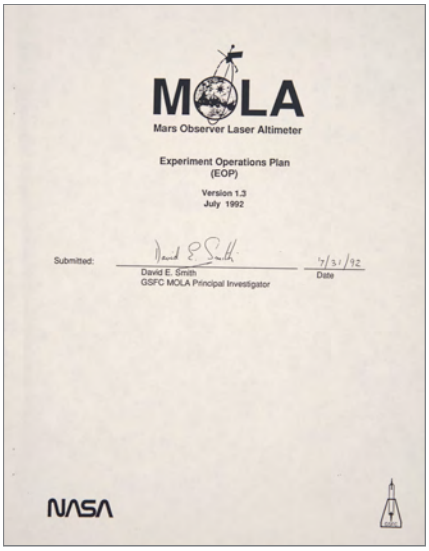
The hard work done by the scientists and engineers who worked on MOLA is preserved in the records they created throughout the process. From design, testing, and integration to reviews and launch, the records tell the story of MOLA. The Goddard Archives was able to accession the records from the Mars Observer Laser Altimeter and the Mars Orbiter Laser Altimeter by way of the Federal Records Center. When a mission, program, or project closes out, its temporary records are held for a certain amount of time, while its permanent records are sent to the National Archives and Records Administration (NARA). As part of the federal records life cycle, once the temporary records reach the end of their retention period, they can be destroyed. The MOLA instrument records reached the end of their retention period, but the archives staff knew they would be valuable to scientists, engineers, and researchers for

Records from NASA's Mars Laser Altimeter Story Live On (continued)


MOLA
Mars Observer Laser Altimeter
Experiment Operations Plan
(EOP)
Version 1.3
July 1992
Submitted: David E. Smith 7/31/92
David E. Smith
GSFC MOLA Principal Investigator
Date
NASA

↑ Cover of the MOLA Experiment Operations Plan signed by the principal investigator, David E. Smith. (Image credit: NASA/Goddard Archives)

years to come, so they were accessioned into the Goddard Archives, where they will reside in perpetuity.

The MOLA records arrived at the Goddard Archives in two accessions, one for the Mars Orbiter Laser Altimeter and one for the Mars Observer Laser Altimeter. After they arrived, the records were processed. Processing is an archival function that is integral to making records searchable. Processing involves identifying the original order of the materials or creating an order if no order is discernable. Some level of holdings maintenance is usually performed during processing as well. Both collections were organized and placed into archival-quality housings. Rusty staples and paperclips were removed and replaced with stainless steel paperclips. As the collection was processed, the archivist gathered information about the records to include in the archival description. The archival description and metadata within are what allows the records to be searchable in our online catalog. ■

MOLA RECORDS IN LIDAR DOCUMENTARY SERIES

Watch Goddard Space Flight Center's *Leaders in Lidar* series, which features a few MOLA records in chapter 1: "The Laser Is Better!"

Reforming JPL for Competed Missions (continued from page 5)

4 Neufeld, "Transforming Solar System Exploration," pp. 5–12.

5 This was not an accident. The Mars Pathfinder team not only was aware of the original Lockheed "Skunk Works," but they also visited the so-called "Batcave" operations center for the Clementine lunar mission. See also Howard McCurdy, *Faster, Better, Cheaper: Low-Cost Innovation in the U.S. Space Program* (Baltimore: Johns Hopkins University Press, 2001).

6 Peter Westwick's *Into the Black: JPL and the American Space Program, 1976–2004* (New Haven: Yale University Press, 2007), pp. 228–240, covers the TQM and reengineering drives at JPL in some detail.

7 E. Kane Casani, "Reengineering the JPL Project Design Process," D-11785, 13 May 1994, p. 2.

8 Quoted from Casani, "Reengineering the JPL Project Design Process," p. 16; original source was Steve Harrison and S. Minneman, "Design Tools for the Communication Age," *Stanford Design Experience*, 24 March 1994.

9 Office of the Under Secretary of Defense (Acquisition and Technology), *DoD Integrated Product and Process Development Handbook*, https://www.secnav.navy.mil/rda/onesource/documents/program%20assistance%20and%20tools/handbooks,%20guides%20and%20reports/page%203/ippdhdbk.pdf (accessed 8 August 2023).

10 Jeffrey L. Smith, "Concurrent Engineering in the Jet Propulsion Laboratory Project Design Center," ASME, 1998.

11 Stephen D. Wall, "Reinventing the Design Process: Teams and Models," Jet Propulsion Laboratory, 1999, https://ntrs.nasa.gov/api/citations/20000056941/downloads/20000056941.pdf (accessed 23 August 2023).

12 Ibid.

The Ballad of Clementine

A Successful, but Little Heralded, Spacecraft

» By **Steve Garber**, Historian, NASA Headquarters
and **James Anderson**, Historian, Ames Research Center

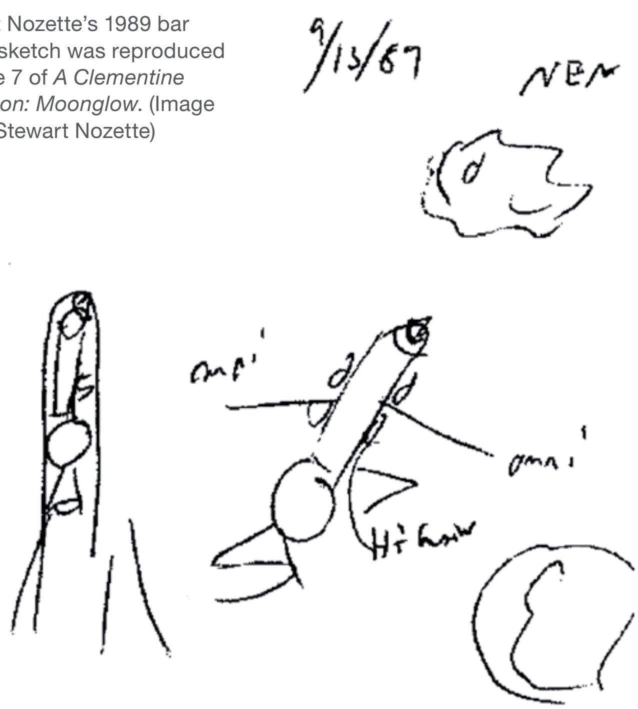
AS STEWART NOZETTE liked to tell the story, it all began in a Washington, DC, bar in September 1989. Nozette, then a young geoscientist, was talking with Pete Worden, a National Space Council staffer, and Geoffrey Tudor, a Capitol Hill staffer, and sketched a concept on a bar napkin for an innovative, low-cost mission to validate new space technologies being developed by the military's Strategic Defense Initiative (SDI) that would have spinoff value for NASA.[1]

NASA's involvement with Clementine was both partial and ancillary. Nevertheless, as an example of collaboration between NASA and the Department of Defense (DOD), the mission's approach to operations, and its attempt to include (eventually) scientific considerations, all offer fruitful areas for a comparative study. While numerous reports, papers, and accounts have documented the Clementine mission and made a case for its impact, the mission has, unfortunately, generated little sustained attention from a historical standpoint. It is our hope that renewed attention to this unique mission could stimulate some in-depth and critical assessments, placing the mission in its context and drawing useful insights for today.[2]

For Clementine, things progressed relatively quickly, with the formal birth of the mission about two years after Nozette, Worden, and Tudor discussed the concept over drinks.[3] DOD's Ballistic Missile Defense Organization (BMDO) funded and ran the program, and it selected the Naval Research Laboratory (NRL) to design, build, and operate a low-cost spacecraft to orbit the Moon and fly by an asteroid named Geographos. Scientists were brought aboard the team later in its development to get what scientific data they could from the mission, a decidedly secondary goal that ended up yielding at least one significant discovery and much knowledge about the Moon. As the first U.S. spacecraft to travel to the Moon since the Apollo 17 mission in 1972, Clementine launched on 25 January 1994, less than two years after project initiation. Although it never made it to Geographos, it successfully demonstrated innovative new technologies, very successfully mapped the Moon, showed how DOD and NASA could fruitfully cooperate, and paved the way for a new "faster, better, cheaper" approach to building and operating spacecraft.

While NASA Administrator Daniel Goldin became known for pushing NASA to implement "faster, better, cheaper" missions in the 1990s, Clementine may well be considered

Stewart Nozette's 1989 bar napkin sketch was reproduced on page 7 of *A Clementine Collection: Moonglow*. (Image credit: Stewart Nozette)



the first actual success story of this approach.[4] Interestingly, BMDO provided funding to design, build, and operate the Clementine spacecraft. NASA Goddard Space Flight Center personnel provided key mission design (trajectory) support for the lunar mapping phase; Jet Propulsion Laboratory staff did this for the asteroid flyby mission; and NASA's Deep Space Network (DSN) infrastructure provided communications support to the ground segment.

Clementine cost BMDO approximately $75 million total, a sharp contrast to the much more expensive "flagship, Battlestar Galactica" spacecraft that were common at the time. Specifically, it cost $55 million to build the spacecraft and $20 million for the launch (it saved money by using a refurbished Titan II intercontinental ballistic missile). Curiously, it was actually less expensive to send Clementine into deep space to test BMDO's target acquisition technology than to do so in Earth orbit because the latter would have involved building and launching artificial targets as well.[5] In addition to the Moon and Geographos, Clementine's Interstage Adapter was designed to be a target for the spacecraft's sensors and collect data on the cis-lunar radiation environment.

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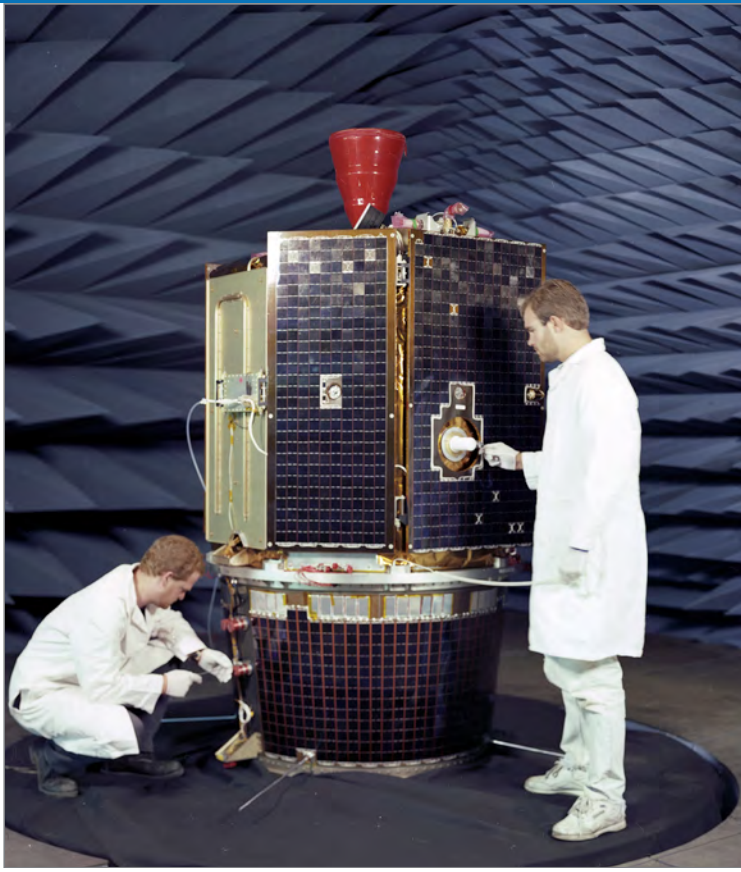

The Clementine spacecraft, on top of its interstage adapter, is prepared for testing in NRL's anechoic chamber. (Image credit: Richard Bussey, U.S. Naval Research Laboratory)

Clementine program managers also adopted an unusual approach to research and development (R&D) by selecting another federal organization, NRL, to design, build, and operate the spacecraft. Program managers recognized that a select few government and university labs had an "end-to-end capability" advantage over industry in that the spacecraft "have been conceived, designed, built, and tested by the scientists and engineers who are responsible for the complete mission, including the analysis and distribution of data, and publication of results. This pride of ownership is a powerful motivator, assuring both productivity and quality."[6] Another program manager echoed this sentiment, noting that "[w]e operate on pride of ownership. The same engineers who built the [Clementine] components are operating them.… If they made any mistakes, now they have to live with them."[7] Program Manager Lieutenant Colonel Pedro "Pete" Rustan also noted that the government was better equipped to build demonstration spacecraft and suggested that industry should be invited in to compete to build the spacecraft once its design was finalized and proven, although some in industry did not like that because they felt that designers and manufacturers should all be on the same team, which was unusual for government spacecraft programs at the time.[8]

Project personnel implemented other management innovations that contributed to Clementine's success. From the outset, the project was designed with dual-use technology in mind: the main goal was to demonstrate BMDO target acquisition sensors that could then later be utilized for civilian spacecraft with scientific aims. The Clementine project was also known for its lean program management, with relatively few staff, and kept the costs to a bare minimum. Developing the spacecraft in-house at NRL, rather than running as a major military acquisition effort, was seen as a way to reduce costs. Additionally, managers realized they could relax military specifications for Clementine and simply use reliable, off-the-shelf microelectronics that were already available commercially.[9]

Technology played a key role in the Clementine project. Its instruments were derived from lightweight sensors from the "Brilliant Eyes" (missile-tracking satellite constellations) and "Brilliant Pebbles" (missile interceptors) SDI programs. The spacecraft project successfully tested various lightweight technologies, including star trackers, a reaction wheel, an autonomous navigation system, a solid state data recorder, composite materials, an innovative nickel-hydrogen battery, optical sensors, solar panels, two new types of gyroscopes, and inertial measurement units. The nickel-hydrogen battery turned out to save the day when a software error caused the solar arrays to point away from the Sun, which would have caused regular batteries to completely discharge, but after operators regained control of the spacecraft and reoriented the arrays, the mission was able to continue.[10] The navigation system also exceeded expectations throughout the mission. Clementine advanced the state of the art in autonomous mission operations with the success of the Spacecraft Autonomous Operations Experiment performed during lunar orbit 303.[11] The Lawrence Livermore National Laboratory (LLNL) developed an ultraviolet/visible light camera and two infrared cameras plus a light detection and ranging (lidar) imaging system, none of which had flown before. The Aerospace Corporation developed a Charged Particle Telescope. All these instruments performed well, thus flight-qualifying these technologies for BMDO.

As one marker of its success, Clementine was the first project highlighted in the foreword to BMDO's 1994 technology transfer report. The commercial sector adopted several specific technologies such as the battery, inertial measurement units, and software.[12]

Despite Clementine's primary focus on technology, it was remarkably successful scientifically.

Despite Clementine's primary focus on technology, it was remarkably successful scientifically. With noted scientist Gene Shoemaker from the U.S. Geological Survey as the science team leader, Clementine produced a "global data base of digital, multispectral images for the Moon," the first for any object in our solar system, and the first set of digital images of the Moon. In 73 days of lunar orbit, Clementine mapped more than 99 percent of the Moon in multiple spectral bands.[13]

It acquired almost two million visible and infrared images of the Moon, which enabled the global mapping of the rocks in the lunar crust and a detailed look at the geology of the Moon's polar regions and far side. In addition, its laser-ranging measurements enabled scientists to map the Moon's global topography.[14] Clementine images were posted online, an early example of the government leveraging the web to engage citizen scientists.

In a headline-grabbing press conference on 3 December 1996, several years after its prime mission had concluded, officials announced that the Clementine team likely had found water ice near the lunar south pole.[15] As part of a bistatic radar experiment, the spacecraft had bounced radio waves from the Moon's poles to Deep Space Network antennas on Earth, which showed that "ice likely makes up part of the Moon's surface layer [of the permanently shadowed craters] near the South Pole" and is the rough volume of a small lake or pond. In addition to its implications for human exploration (potential potable water and rocket fuel), this discovery was remarkable because the Apollo lunar samples had indicated that the Moon was extremely dry. Yet the vast majority of objects hitting the Moon and creating craters are water-rich comets. Perhaps most remarkably, Clementine was not even designed specifically to look for water on the Moon, so scientists improvised this experiment.[16]

Clementine data yielded knowledge about amazing lunar craters, such as the Aitken basin at the south pole: at 7.5 miles deep, it is the biggest, deepest crater in the solar system. Clementine also examined the gravitational field models of the Moon and gave scientists a new, more complex understanding of the Moon's shape, topography, and internal structure.[17]

Despite its successes, the mission certainly had its fair share of problems. During development, two cameras failed vibration testing and had to be rebuilt twice, delaying things by three months. The spacecraft ended up being heavier than engineers had wanted (230 vs. 160 kilograms, not counting fuel).[18] After launch, the upper stage of the Titan II rocket exploded on orbit, creating approximately 600 pieces of debris in low-Earth orbit; thankfully, this neither affected the spacecraft on its way to the Moon nor endangered a Space Shuttle mission that launched only a few days later.[19]

More significantly, after Clementine had been orbiting the Moon for several months, on 7 May 1994, a software test in preparation for the asteroid flyby went awry, causing a cascade of problems. An onboard computer crash caused a Reaction Control System (RCS) thruster to be stuck in the "on" position, causing the spacecraft to spin too quickly, and then draining its RCS propellant. With its planned trip to Geographos suddenly out of the question, ground controllers placed Clementine in a highly eccentric Earth orbit for a couple of years to observe radiation's effects on the spacecraft.[20]

Technicians lower the nose fairing over the Clementine spacecraft before launch. Clementine was launched from Vandenberg Air Force Base on 25 January 1994. (Image credit: Michael Savell, U.S. Naval Research Laboratory)

More generally, planning and operations teams were understaffed and did not have time to rehearse lunar operations ahead of launch. Only three such rehearsals were done on the way to the Moon. Hence, a lot of the team's learning was done literally on the fly, and the team had to improvise to make up for lost orbits.[21] However, once the operations procedures were completed and tested, the operations team set a new paradigm that was used as an example for later NASA and DOD missions.[22]

DOD officials initially planned to fly a second Clementine spacecraft a year or two after its first launch. However, in March 1994, BMDO transferred the Clementine project to the Navy, which decided not to proceed with Clementine II. For the second iteration, Clementine funding was intended to be cost-shared between NASA and DOD. Technology demonstration again would have been the primary mission, with science a secondary objective.[23]

Clementine's legacy also includes laying the groundwork for the Lunar Prospector (a Discovery-class mission), the Lunar Reconnaissance Orbiter (LRO), and the Lunar Crater Observation and Sensing Satellite (LCROSS) missions. It also "changed the direction of the American space program" after the failure of the 1992 Space Exploration Initiative and led to interest in going back to the Moon with humans in the 2004 Vision for Space Exploration.[24] For all these reasons and more, Clementine may rightfully be considered a watershed, if underappreciated, mission. ■

Endnotes

1 Naval Research Laboratory, *A Clementine Collection: Moonglow* (Washington, DC: June 1994), pp. 6–7, gives the account from Nozette. The same Naval Research Laboratory (NRL) report also notes that "[t]he Clementine story began in 1990 when NASA Administrator Richard Truly asked the Department of Defense to consider a joint NASA/DoD mission that would pursue goals mutually beneficial to both organizations" (p. 2). That same year, the origins of what would become NASA's Discovery Program started to emerge as a solution to the increasingly expensive and less numerous planetary science missions of the time. Clementine and Discovery are quite distinct, though they are often cited in the context of the "faster, better, cheaper" approach to building and operating spacecraft.

For more on the Discovery Program, stay tuned for a history book written by Susan Niebur with David Brown that will be published later this year.

2 To that end, we have collected some useful materials from a variety of archival sources in the short course of our research. We also know of one person involved in the mission who may well write a book on Clementine. That said, we would be interested to hear from anybody who might know about other Clementine records and/or is interested in writing about this subject.

3 The project was informally named after the 19th-century folk song "My Darlin' Clementine" about a miner's daughter who drowned and thus was "lost and gone forever." The spacecraft was to help determine the Moon's mineral content and fly by an asteroid, and then it would be "lost and gone forever." See, for example, Stewart Nozette et al., "The Clementine Mission to the Moon: Scientific Overview," *Science* (16 December 1994): 1835. The project was formally known as the Deep Space Program Science Experiment (DSPSE) (despite its primary focus on technology demonstration) until shortly before launch, when it became known as Clementine.

4 See, for example, Howard McCurdy, *Faster, Better, Cheaper: Low-Cost Innovation in the U.S. Space Program* (Baltimore: Johns Hopkins University Press, 2001).

5 Lt. Col. Pedro Rustan, "Clementine: An Experiment to Flight Qualify Lightweight Space Technologies," draft summary, pp. 9–10, Missile Defense Agency historical file 772.

6 This quotation is from Project Manager Lt. Col. Pedro Rustan in Carl Bostrom, "The Clementine Model," *Space News* (16–22 May 1994): 18.

7 This quotation is from NRL Program Manager Paul Regeon in Kathy Sawyer, "Clementine Tells All After Gazing Upon the Moon," *Washington Post* (3 May 1994): A3.

8 Ben Iannotta, "Clementine Called Model for NASA," *Space News* (25 April–1 May 1994): 1, 20.

9 Clementine Executive Overview (undated), p. 4, NASA Headquarters Archives, file 5728.

10 Paul D. Spudis, "The Clementine Mission: A Lesson for NASA?," *Space Times* (May–June 1994): 20–21; Darren L. Burnham, "Faster, Cheaper, Clementine: Around the Moon in 71 Days," *Spaceflight* (September 1994): 309; Clementine Executive Overview, p. 3; Ballistic Missile Defense Organization, *Technology Applications Report 1994*, 1 January 1995, p. 88.

11 Trevor Sorensen, "Global Lunar Mapping by the Clementine Spacecraft," American Astronautical Society (AAS)/American Institute of Aeronautics and Astronautics (AIAA) Spaceflight Mechanics Meeting, Albuquerque, 13–16 February 1995, AAS Paper 95-127, p. 21; Trevor Sorensen et al., "Spacecraft Autonomous Operations Experiment Performed During the Clementine Lunar Mission," *Journal of Spacecraft and Rockets* 32, no. 6 (November–December 1995): 1049–1053.

12 BMDO, *Technology Applications Report 1994*, pp. v and 88.

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14 Stewart Nozette et al., "The Clementine Mission to the Moon: Scientific Overview," *Science* (16 December 1994): 1835.

15 *A Clementine Collection: Moonglow*, p. 3; "Clementine Spacecraft: Ice on the Moon," DOD Fact Sheet, 3 December 1996.

16 "Clementine Spacecraft: Ice on the Moon," DOD Fact Sheet, 3 December 1996; Sorensen and Spudis, "The Clementine Mission—A 10-Year Perspective," p. 664.

17 Kathy Sawyer, "Clementine Tells All After Gazing upon the Moon," *Washington Post* (3 May 1994): A3; Maria T. Zuber et al., "The Shape and Internal Structure of the Moon from the Clementine Mission," *Science* (16 December 1994): 1839.

18 "Clementine to Mark U.S. Return to Moon," *Aviation Week and Space Technology* (17 January 1994): 66–67, cited in Burnham, "Faster, Cheaper, Clementine," pp. 309–312.

19 "Titan 2 Stage Explodes in Orbit Used by Shuttle," *Space News* (14–20 February 1994): 2; "Discovery Unscathed from Titan Breakup," *Space News* (21–27 February 1994). STS-60 (Discovery) launched on 4 February 1994. It was unclear whether leftover rocket fuel or a collision with an existing piece of debris caused the explosion of the Titan II upper stage.

20 "Sensors Misdirected: Clementine to Forgo Geographos Fly-By," *Space News* (23–29 May 1994): 22, cited in Burnham, "Faster, Cheaper, Clementine," p. 312, and Kathy Sawyer, "Spacecraft That Was Aimed at Asteroid To Be Diverted to Near-Earth Mission," *Washington Post* (19 May 1994): A28; Sorensen and Spudis, "The Clementine Mission—A 10-Year Perspective."

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23 Ben Iannotta, "Clementine Readied for Launch," *Space News* (17–23 January 1994): 10; "Clementine Transferred from BMDO to the Navy," *Defense Daily* (3 March 1994): 328; "SDIO Planning Clementine Follow-On," *Defense Daily* (29 March 1993): 465; Ben Iannotta, "Pentagon Urges NASA To Help Send Alice Straight to the Moon," *Space News* (14–20 March 1994); "Air Force Discloses Rover Experiment Information," *Space News* (23–29 May 1994): 16; Burnham, "Faster, Cheaper, Clementine," p. 313. Curiously, a lunar rover might have been built for Clementine II.

24 Paul Spudis, "Clementine—The Legacy, Twenty Years On," *Air & Space Magazine* (21 January 2014).

ORAL HISTORY

The Human Side of Discovery

» By **Sandra Johnson**, Oral History Lead, Johnson Space Center

Jim Garvin poses with the DAVINCI descent sphere ("probe") engineering test unit and "the eye of Venus" (Sapphire window held in his hands). (Image credit: NASA/Goddard Space Flight Center)

NASA HISTORIANS collect and publish oral history interviews from individuals across the Agency to provide researchers with valuable first-hand experiences, lessons learned, methodologies for success, and institutional knowledge, which in turn can help inform and ensure the success of future programs. Recently, the Science Mission Directorate tasked the History Office with initiating an oral history project to collect a series of interviews with team members involved in the Discovery Program's historic planetary exploration missions over the last 30 years.

Approved by Congress in 1993, the Discovery Program ushered in a new concept for low-cost, competed science missions within our solar system. Compared to NASA's large and costly flagship programs, these Discovery missions stay under an established cost cap but remain high-value and focused studies that are competitively selected and led by a principal investigator (PI). In the last 30 years, the flown spacecraft and scientific instruments have changed the way we think about our solar system and reshaped the position of science and investigators in the selection, planning, and management of exploration missions.

In his Discovery Program oral history, Dr. James Garvin, Chief Scientist at Goddard Space Flight Center and PI for the DAVINCI mission, spoke about how the idea of competition for science investigations was born out of a tragic event—the loss of the STS-51L Challenger crew. The following are excerpts from one of his transcripts.

"After the Challenger disaster, I was very fortunate that NASA assigned me to be a member of Sally Ride's team that was asked to reassess [NASA's] leadership in space. There were ten of us from across the Centers brought together with Sally, who was of course an incredible inspirational person beyond words and just a joy to work with, to ask the tough questions. What is leadership after you've had a horrible setback, a calamitous one, that none of us will ever forget? …I'd only been at NASA a year at that point and couldn't believe it. But to work with these colleagues—and I was the lone scientist on Sally Ride's committee other than Sally herself, who of course was an astronaut, a scientist—to think about what it would be to establish leadership at the space frontier.

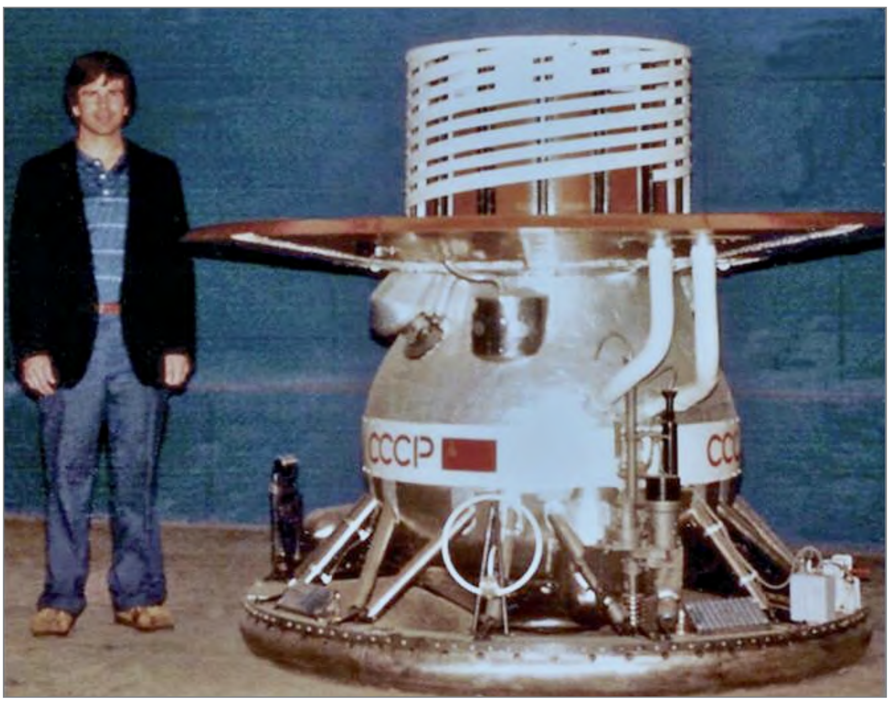
> "…working for her I saw NASA writ large."

But working for her I saw NASA writ large. We briefed the Administrator about some of these leadership ideas. It was amazing. Talking about where we can send people, what's coming after Shuttle, how we're going to build what became the ISS. It gave me an opportunity to think about how we do the next-generation aspirational science. What's the business model? The thing that Sally liked was that it's great when people compete, like the Olympics, music, the arts, whatever. In some sense Sally's idea about competing the action amongst teams of women and men through science, even the robotic science of exploring planets, started ideas including the now 30-year-old Discovery Program.

We saw her testimony to one of the congressional committees. She testified that we have to compete. Not everything, but the more competition we get, the better the teams will be to do the jobs we need in scientific exploration. Science is always competitive, we compete through peer review, we compete through getting things published, we compete for lab space, for experiment space, for money, for what we learn. When you put that together it's going to give you better value.

That was somewhat heretical in a sense. We had small competitions at NASA, we're going to do this mission and we'll get some people, and those will be sort of competed at an investigator level. But competing everything, an entire mission, the rocket, the spacecraft, the instruments, the science team, management team, that was still not yet in vogue. Sally's catalytic listening to what leadership meant gave us the ability to start programs like Discovery to send smaller spacecraft to achieve big science. But that was a big change.

↓ As a Ph.D. student at Brown University, Jim Garvin visited the USSR in 1983 to work on Venera 13 and 14 lander data concerning Venus. He is standing next to the Venera 13 lander in Moscow Space Museum to celebrate his work on data from this mission. (Image credit: Don Campbell)



> “Sally's catalytic listening to what leadership meant gave us the ability to start programs like Discovery to send smaller spacecraft to achieve big science.”

It went from an era where we had “new starts,” smoke-filled rooms, people behind closed doors, let's do a mission there, and then lots of scientists meet, and engineers said, ‘We can do that, not this.’ Boom, we're doing missions. That worked. We flew Voyager and Viking, Galileo that way. But the future has changed and the Discovery Program now 30 years old is showing the value of that competition.

It's tough, it takes time and energy and money. But in the end the products are just spectacular. I was lucky to see that as it happened, as it came out of Sally's wisdom, and to start pushing for things that were part of my career. And now, thanks to the Discovery Program, we have a mission to Venus that will return the United States to the atmosphere and the surface of Venus for the first time in 50 years. As the principal investigator on that mission, having gone through the Discovery lens, it's exciting to have a team of many brilliant young people to work with this mission across many NASA Centers, including teammates from JPL, JSC, Ames, Langley, Goddard, and many universities and Lockheed Martin to do a mission like this. ”

The Human Side of Discovery (continued)

Find out more about NASA's Discovery Program.

Communication—across teams and with the public—is an ongoing theme in the oral histories collected thus far for this project. One of the main objectives of the Discovery Program is to "announce scientific progress and results in the peer-reviewed literature, popular media, scholastic curricula, and materials that can be used to inspire and motivate students to pursue careers in science, technology, engineering, and mathematics."[1] Likewise, the National Aeronautics and Space Act of 1958 states that NASA shall: "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

In his oral history, Dr. Garvin explained his thoughts on the importance of communicating NASA's goals and accomplishments to inspire the next generation:

"We serve at the behest of the public to have the opportunity to extend our presence in this universe as per the Space Act of '58. Part of that job is communicating what we do. We train our astronauts to do that and they do a great job of course.…But I think all of us have a little piece of that to do. It's not just the social media things, it's communicating why this matters. Sometimes why it matters is lost on the esoterica of what we're doing. 'Why are we listening to marsquakes?' Another planet might tell us something about ourselves that we didn't realize was happening because we weren't smart enough to think outside of the Earth box. …Communicating the excitement and passion for what we have done, can do, want to do within these envelopes is important. Someone once told me Discovery missions are about the cost of a Hollywood movie. For the price of a movie that we're entertained by…we're going to explore a new world for the first time ever. The first time ever!

> "Someone once told me Discovery missions are about the cost of a Hollywood movie. For the price of a movie that we're entertained by… we're going to explore a new world for the first time ever. The first time ever!"

When you start doing that for the first time ever, you have to communicate that excitement. I think there's a lot of naturally gifted communicators. I call them science-casters instead of sportscasters. But those science-casting women and men, the ones I've been dazzled by and I've learned from, they're just natural at explaining what they're doing and why. But not in the way they could convey to their colleagues at a science conference… but in the excitement of what that meant to you and your team.

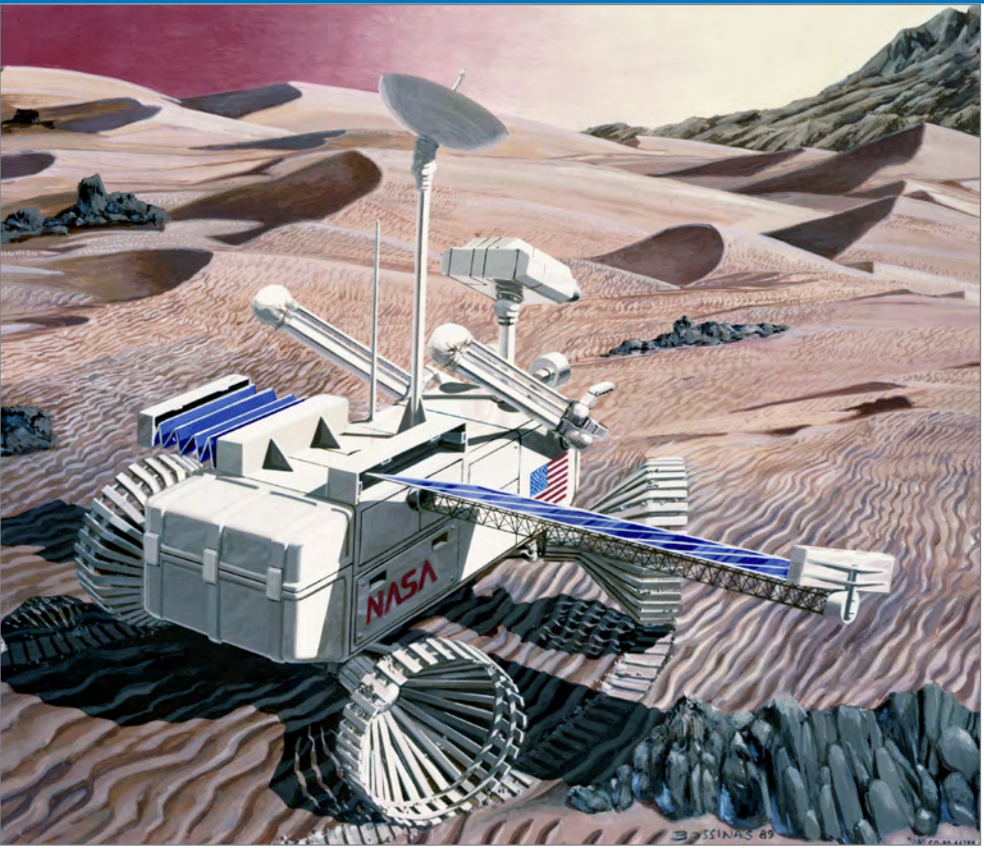
Just an example, our DAVINCI team will employ 1,600 to 2,000 people as we build our mission to Venus. It's a lot of great folks. Every one of them have their story to tell of their piece of doing something that has not been done in this way ever before. That's pretty cool. When we were presenting DAVINCI to the selecting official, we made a set of selfie videos. We asked 40 or 50 people to each record a minute of themselves talking about why going to Venus might be interesting to their neighbor or their family members. We pasted them together in a little video collage. To just see the excitement of people was tremendous!

Our DAVINCI project scientist was standing next to a babbling brook. She said, 'I like water. What happened to the water on Venus? I want to know. I have to go to find out. Planets may be telling us special things; we just don't know.' I think the communication element is an exciting part of it. I've taken it seriously; on DAVINCI we take it massively seriously. In fact, many people on our team are incredibly gifted communicators. One of our deputy PIs is one of the best I've ever seen. Literally off the charts. I hope she gives most of our talks. Our two deputies are both incredibly gifted in that regard because they can tell a story better than I ever could. Such talent is inspiring."

Endnote

1 See https://beta.science.nasa.gov/planetary-science/programs/discovery/.

Learn about NASA's Oral History Program and read more interview transcripts.



Artist Les Bossinas created this conceptual depiction of a rover for a lunar base in 1989. (Image credit: NASA/GRC)

Former Glenn Artist Brings Future Space Missions to Life

» By **Robert Arrighi**, Historian, Glenn Research Center

ENGINEERS OFTEN WORK on complex or esoteric projects that are difficult for others to visualize. So they often turn to NASA graphic artists to bring their concepts to life. Illustrators, such as Les Bossinas at NASA's Glenn Research Center (GRC), can provide colorful representations that bring otherwise drab reports or briefings to life. In the late 1980s and 1990s, Bossinas became renowned for his imaginative depictions of space settlements, conceptual space vehicles, and futuristic uses of a space station. Many of these paintings are still being used today.

Bossinas became interested in drawing, particularly depicting mechanical objects such as vehicles, while growing up in northeast Ohio. After serving in the Korean War, Bossinas earned a bachelor's degree in fine arts from Ohio University in 1961. He subsequently worked for years as an industry graphic artist in the Cleveland area.

In 1984, Bossinas joined the Graphics and Exhibits Branch at NASA Glenn (then named Lewis Research Center). Although he did not have an aerospace background, Bossinas quickly adapted to the new subject matter. One of his first assignments was to create a series of paintings for the center's Educational Services Office depicting different elements of a theoretical Moon base.

Bossinas won acclaim in 1986 with an illustration of a theoretical hypersonic aircraft with its surface glowing from the extreme temperatures experienced during high-speed flight. The image was later used as the cover of T. A. Heppenheimer's *Facing the Heat Barrier: A History of Hypersonics* (NASA SP-3232).

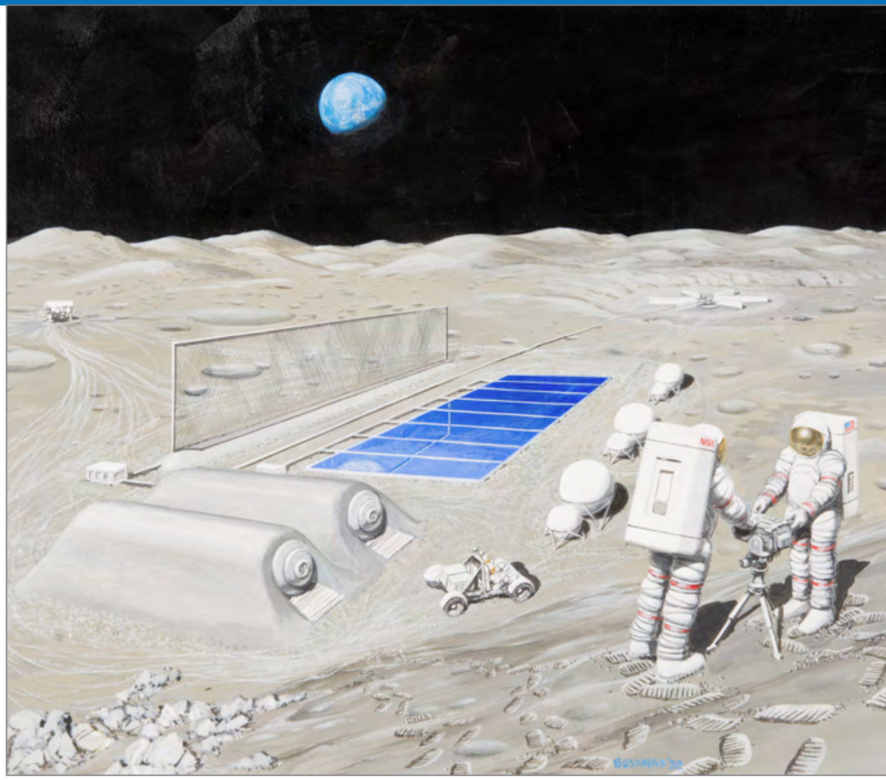
Bossinas was responsible for producing graphical representations of objects or concepts for engineering or managerial customers. Sometimes this involved creating schematic or architectural drawings for specific objects; other times he was tasked with designing logos or

Bossinas's depiction of a glowing hypersonic aircraft was displayed as part of NASA's exhibit at the 1986 Experimental Aircraft Association (EAA) convention in Oshkosh, Wisconsin, and was subsequently used in a number of NASA publications and presentations. (Image credit: NASA/GRC)

Former Glenn Artist Brings Future Space Missions to Life (continued)

Bossinas at work in his studio. He won first, second, and third place in the Lewis Art Show in 1990. (Image credit: NASA/GRC)

Bossinas at work creating digital artwork in May 1996. While he never gave up traditional illustration methods, Bossinas regularly took advantage of the possibilities that digital tools allow. (Image credit: NASA/GRC)



In this 1992 illustration, Bossinas visualizes a lunar base with an electrostatic fence. (Image credit: NASA/GRC)

decorative objects. Not surprisingly, though, Bossinas's favorite assignments were the ones requiring the greatest imagination and artistry—the visualization of futuristic scenes or missions.

Typically, a project started when engineers would approach him with ideas for a new concept or mission. Bossinas would discuss the subject with them and perform his own research. Most illustrations went through several iterations and reviews with the customer before being finalized.

The introduction of NASA's Space Exploration Initiative in 1989 brought an increased demand for novel space exploration illustrations, particularly space settlements. The pieces sometimes depicted a specific technology, such as photovoltaic systems being utilized to power an outpost on the Moon, or they might be more general, such as showing what the use of in situ materials on a Mars colony might look like.

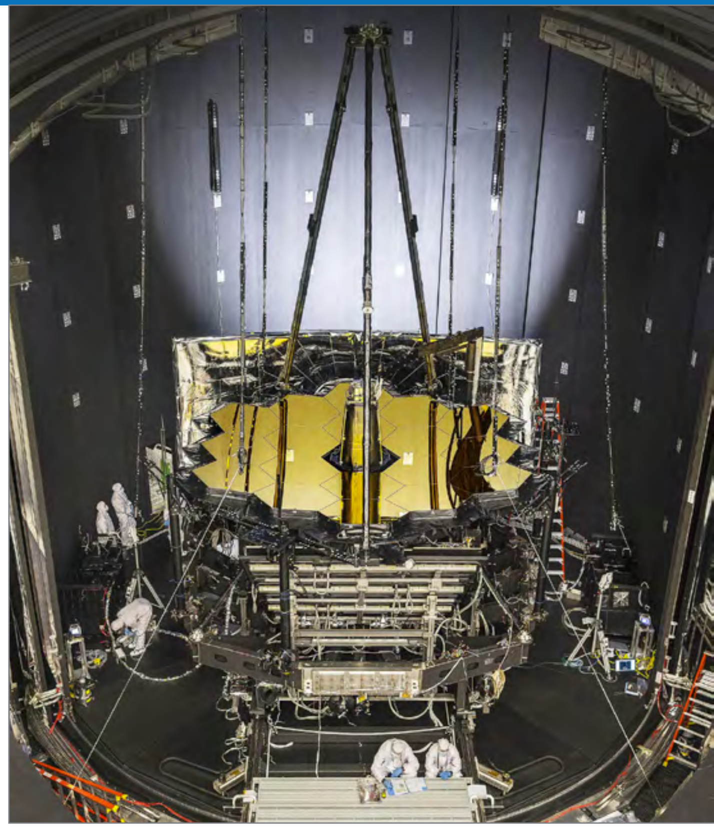
Glenn's illustration team received its first graphics computer in the early 1990s. At first Bossinas was too busy to set aside time to learn how to use it. Once he received training, though, he became awed by its potential. Bossinas frequently utilized the machine for his art thereafter and found it particularly helpful in making modifications to illustrations.

After retiring from NASA in 2001, Bossinas has continued painting and began working with stained glass. He has shared his experiences with younger artists and has occasionally participated in large events such as the Smithsonian Folk Festival and the Ingenuity Festival in Cleveland. Several of his conceptual space paintings were included in a NASA art exhibit in the Cleveland Hopkins International Airport in 2016.

Weathering the Storm

Space Environment Testing of the Webb Telescope

» By **Jennifer Ross-Nazzal**, Historian, Johnson Space Center



↑ The James Webb Space Telescope was placed in Johnson Space Center's historic Chamber A on 20 June 2017 to prepare for three months of testing in a cryogenic vacuum that mimics temperatures in space. (Image credit: NASA)

IN JULY 2022, NASA released the debut images from the James Webb Space Telescope. At the event, President Joe Biden said that the photographs would "remind the world that America can do big things and remind the American people—especially our children—that there's nothing beyond our capacity. We can see possibilities no one has ever seen before. We can go places no one has ever gone before."[1] Thousands of scientists, engineers, and technicians from NASA and industry built, tested, and integrated the telescope, making these images possible, including those who worked at the Space Environment Simulation Laboratory (SESL) at Johnson Space Center (JSC) in Houston.

When compared to other NASA facilities, JSC is not usually recognized for its contributions to astronomy and solar system exploration. JSC has always been NASA's premier human spaceflight center and home to the astronaut corps, and today it serves as the lead center for the International Space Station, the Orion spacecraft, and Gateway. But in 2006, NASA selected SESL's Chamber A to perform a vital cryogenic vacuum test that gave scientists and engineers the confidence that the next-generation telescope would function as intended in space. The test was particularly memorable for many members of the team because it occurred during a major hurricane that dumped more than 50 inches of rain on the Houston area, causing catastrophic flooding. Hurricane Harvey resulted in more than $125 billion in damages, making it the second most damaging hurricane to hit the United States, just behind Hurricane Katrina.

The SESL is one of the Center's National Historic Landmarks, and significant modifications had to be made to the facility before the test could begin. The building, completed in 1964, featured two chambers. Chamber A, the larger of the two, tested the Apollo Command and Service Module to ensure that the vehicle could safely house the astronauts in the heat and cold of space. Both chambers were designed to protect test subjects. To protect astronauts, technicians, and engineers working inside the area, NASA ensured that the test chamber could be quickly repressurized in an emergency—in a matter of seconds. Test conductors monitored participants through portholes and closed-circuit TV, while instrumentation measured their heart and respiration rates as well as oxygen flow rate to ensure that their bodies were not experiencing any undue stress.[2]

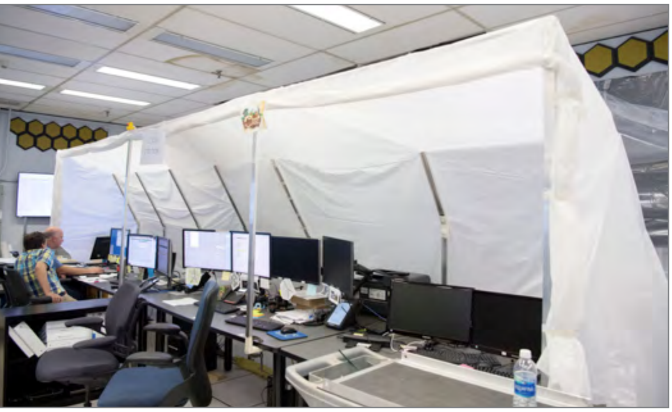
But testing a telescope is not like testing a human-rated spacecraft and its crew, so requirements for Webb differed from those for Apollo. The Command Module circled Earth and the Moon, experiencing both high and low temperatures, but its lowest temperature of –100 degrees Fahrenheit (°F) was nowhere near what Webb would encounter.[3] Since the telescope was designed to orbit the Sun, one million miles away from Earth, the testing chamber had to be able to recreate the environment in which the telescope would operate: 45 kelvins, or about –380 °F.

Lee Feinberg, the Optical Telescope Element manager for the Webb team, called the cryogenic test "the hardest engineering problem" they faced.[4] The test they envisioned would be complicated, and eventually the team concluded that the original location they chose, NASA's Plum Brook Station in Ohio, was less than ideal. JSC's Chamber A, while not perfect, could be updated to meet their needs. Upgrades included the installation of a clean room, helium shrouds, and an improved liquid nitrogen system.[5] Planning and designing the test took three years, and retrofitting the chamber ended up taking another three years.[6]

Making the decision to relocate the test to Houston added another complication for the test team. Because of Houston's proximity to the Gulf of Mexico and the possibility that the test might happen in the middle of summer, the team had to plan for all contingencies, including a hurricane. "It was almost a running joke about hurricanes," Feinberg remembered. "The likelihood was just incredibly small."[7] Still, they prepared. They stored food, water, and flashlights in lockers just in case, and they even rented a porta potty.[8]

In August 2017, just as the facility reached its working temperature of –387 °F, Hurricane Harvey headed toward the Texas coast and made landfall as a Category 4 storm. (The last Category 4 storm to hit Texas had occurred in 1961—right before NASA announced its decision to build the Manned Spacecraft Center in Houston.) The eye of the hurricane first made landfall on San Jose Island and then the communities of Rockport and Fulton, destroying and damaging property. The storm stalled over southeast Texas, which included the greater Houston and Galveston area, bringing record rainfall and flooding to the area. Thousands lost their homes to the rising water, including some JSC employees and their families. But the test continued because "the chamber was the safest place" for the Webb to be, and the team had taken precautions to prepare—just in case.[9] But the testing team had expected the storm move quickly through the area, not to sit over the region. Even as the ceiling in the control rooms began to leak, testing continued. Staff had to mop up water and cover their systems with tarps, but somehow, the power at the Center stayed on. As if a hurricane and sitting under a leaking ceiling were not stressful enough, another possible obstacle soon emerged—the SESL's liquid nitrogen, which kept the chamber cold, began to run low. Suppliers could not deliver due to massive flooding in the Houston area, but luckily staff did not have to halt the test—the SESL had enough liquid nitrogen in its tanks to make it through to the end.

Tarps protect computing equipment from a leak in the SESL control room ceiling during Hurricane Harvey. (Image credit: NASA)



About eight weeks later, on 18 November 2017, technicians opened the door to SESL's Chamber A, marking the end of the cryogenic testing. Completing the test gave NASA confidence that the James Webb Space Telescope would operate successfully in deep space. The newly upgraded facility was able to meet the program's requirements, saving time and money in the process and resulting in some of the most amazing photos of the early universe. ■

Endnotes

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2. Aleck Bond, interview by Robert Merrifield, 10 October 1967, transcript, JSC History Collection, University of Houston–Clear Lake, Houston, TX.
3. Jonathan L. Homan, interview by author, 28 June 2018, transcript, JSC Oral History Project.
4. "We Are Not Alone: Nobel Laureate in Austin," *Sun News Austin* (11 June 2018), http://sunnewsaustin.com/2018/06/11/we-are-not-alone-nobel-laureate-in-austin/ (accessed 25 August 2023).
5. Lee D. Feinberg, interview by author, 3 July 2018, transcript, JSC Oral History Project.
6. Jonathan L. Homan et al., "Creating the Deep Space Environment for Testing the James Webb Space Telescope at NASA Johnson Space Center's Chamber A," International Conference on Environmental Systems, 14–18 July 2013, https://doi.org/10.2514/6.2013-3522 (accessed 25 August 2023).
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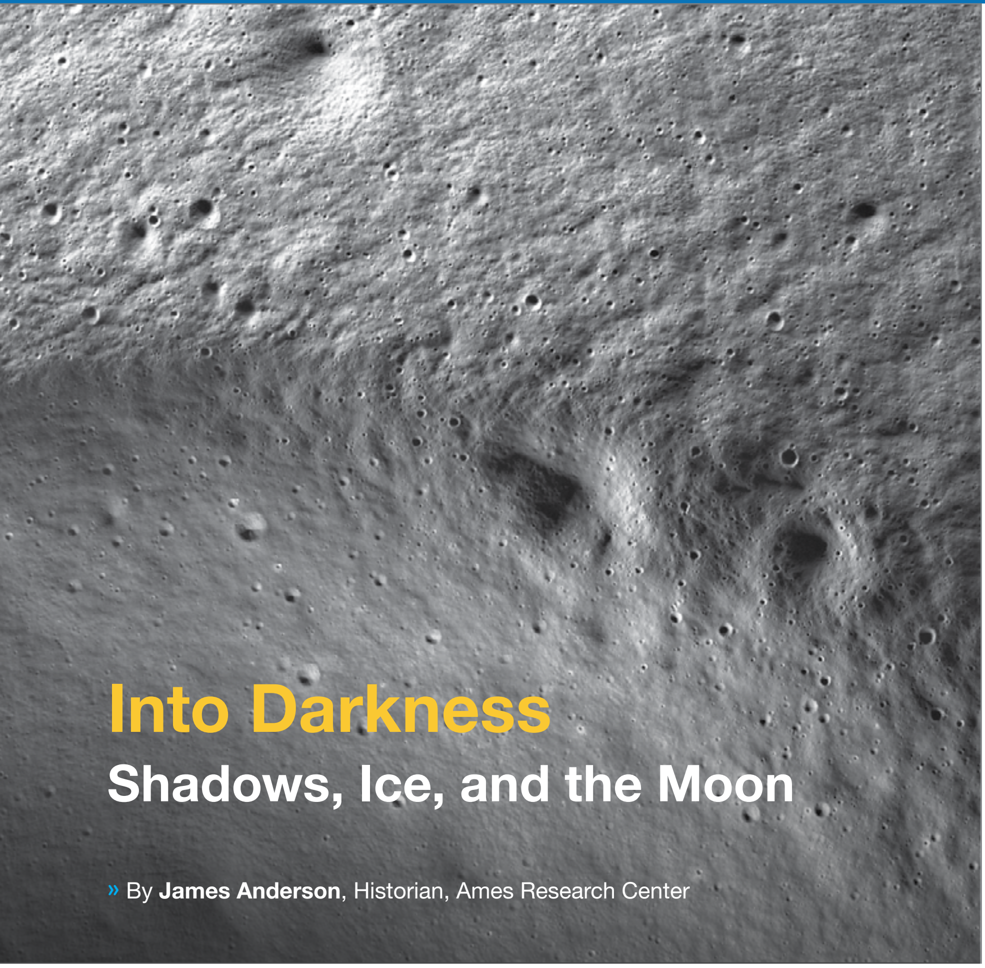
9. Begoña Vila Costas, interview by author, 29 August 2018, transcript, JSC Oral History Project.



Into Darkness

Shadows, Ice, and the Moon

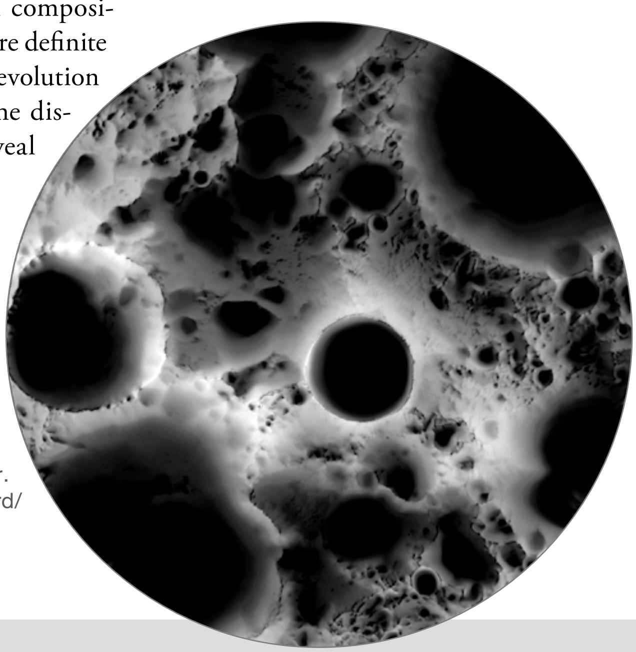
» By **James Anderson**, Historian, Ames Research Center

← The rim of Marvin crater arcs across the image from left to right. The steep interior wall below the rim slopes down toward the bottom of the image. The crater interior is in permanent shadow; the exterior was in shadow when this image sequence was acquired on 28 February 2023. However, this area is not permanently shadowed. The image width is 2,200 meters, and the lunar south pole is about 26 kilometers to the right. This mosaic is made from ShadowCam images M017882983, M017890053, and M017904198. (Image credit: NASA/KARI/ Arizona State University)

DARKNESS AND SHADOW are common tropes often associated with concealment. Shining a light into the darkness, as the metaphor goes, reveals what was once hidden. As NASA explores the secrets of the universe for the benefit of all, some of the universe's secrets are, quite literally, in shadow.

Permanently Shadowed Regions, or PSRs, are found on various surface locations in the solar system. On the Moon, its slight 1.5-degree axial tilt means that crater floors at the poles of the Moon never see direct sunlight. Other polar regions, meanwhile, experience almost constant sunlight. More than an awe-inspiring geographical curiosity, one of the consequences of perpetual darkness is that PSRs are uniquely suited for preserving volatile compounds—including water ice—that would otherwise disperse out into space. These regions are of particular interest for both science and exploration because their chemical compositions will provide us with more definite clues about the origin and evolution of the solar system, while the distribution of ice will also reveal the specific challenges that await for any future harnessing of that ice as a resource. Water ice is present in a variety of locations in the solar system, but no other celestial body is as close to Earth as the Moon and its areas of perpetual darkness.

In the early 1950s, Harold Urey proposed that there could be such regions on the Moon where sunlight never shines. Additionally, there could be volatile substances present in those regions, but Urey specifically ruled out water ice existing in them for any long period of time. In 1961, years before the first successful soft landing on the Moon, NASA funding supported the work of California Institute of Technology (Caltech) scientists



→ Permanently Shadowed Regions, or PSRs, appear black in this multitemporal illumination map of the lunar south pole from the Lunar Reconnaissance Orbiter Camera dataset. The nearly white areas are in almost perpetual sunlight throughout a lunar year. (Image credit: NASA/Goddard/ Arizona State University)

↑ At NASA's Ames Research Center, a lab designed to mimic lunar terrain as it would appear in different areas at the Moon's poles is where the VIPER team tests out lighting systems for the rover with a very low-angle illumination simulating the Sun. The VIPER team has tested several robust light-emitting diode (LED) lighting systems—including blue lights and other wavelengths—to see which would offer the best optical performance for the rover on the Moon. The Ames-based team will pass their findings on to VIPER teammates at NASA's Johnson Space Center in Houston, where the lights will eventually be built. (Image credit: NASA/Dominic Hart)

Kenneth Watson, Bruce Murray, and Harrison Brown, who first suggested[1] and then theoretically demonstrated "that water is actually by far the most stable of the naturally occurring volatile substances…on the lunar surface."[2] Unfortunately, the three authors observed, the very darkness that enabled the cold temperatures and allowed ice to persist would also require placing an instrument in one of those cold traps to make a measurement.[3] It could not be done from Earth or even in lunar orbit. No mission to the lunar surface in the 20th century addressed this outstanding issue.

Instead, the post-Apollo world of planetary missions focused on just about everything except the Moon. After six crewed landings, with their surface experiments, rovers, and hundreds of pounds of lunar samples returned, this change in focus was understandable. From a funding standpoint, however, a retraction of planetary missions began even before the Apollo 11 Moon landing. NASA's share of total federal spending peaked in 1966; as funding for the Agency as a whole was throttled back, scientific projects that did not directly support Apollo had to adapt. The robotic lunar missions of the 1960s primarily supported Apollo landing site selection; scientific exploration was an auxiliary bonus. While planetary missions and space sciences, generally, flourished with programs like Explorers, Pioneer, and Mariner, austerity began to take hold. Meanwhile, as lunar samples were studied on Earth and the lack of water contained in those samples surprised no one, the lunar cold trap theory from 1961 was revisited by James Arnold, who bolstered the original case but still concluded that the lunar ice question remained open and would require experimentation to settle.[4]

Arnold's suggested experiment still has not been conducted yet, but missions since the 1990s have only added to the growing body of evidence that indicates that water ice exists at the Moon's poles.[5] A clear understanding of the nature and distribution of that ice and volatile compounds, however, requires ground-truthing. With advances in imaging capabilities, such as the NASA-funded ShadowCam instrument on board the Korea Aerospace Research Institute's (KARI's) Korea Pathfinder Lunar Orbiter, the permanently shadowed regions of the Moon are coming into view, but we are still in the dark about the details until we physically inspect a sample of regolith from a

…we are still in the dark about the details until we physically inspect a sample of regolith from a PSR.

Into Darkness (continued)

VIPER's lights use arrays of LEDs and will offer the same flexibility as a car's high beams and parking lights. Mounted on a mast, two of these arrays will cast a narrow, long-distance beam. Around the base of the rover, as many as six lights will illuminate a broad area less intensely and can be turned on and off individually as needed. (Image credit: NASA/Daniel Rutter)

Get the latest news about NASA's VIPER mission.

PSR. If NASA's Volatiles Investigating Polar Exploration Rover (VIPER) does become the first mission to venture successfully into a PSR, it will do so as the first rover with headlights, enabling the operators to see the terrain around the rover as they drive. While the headlights will literally illuminate the lunar terrain, it will be VIPER's science payload and drill that shed the metaphorical light on the darkness. ■

Endnotes

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2. Kenneth Watson, Bruce C. Murray, and Harrison Brown, "The Behavior of Volatiles on the Lunar Surface," *Journal of Geophysical Research* 66, no. 9 (1961): 3033.
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4. James R. Arnold, "Ice in the Lunar Polar Regions," *Journal of Geophysical Research: Solid Earth* 84, no. B10 (1979): 5659–5668.
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A Soyuz rocket launches Russia's Luna-25 lunar lander on 11 August 2023. (Image credit: Roscosmos)

Relaunching Russia's Planetary Science Program

» By **Travis Frederick**, Ph.D. Candidate at Princeton University, Fellow at the Kennan Institute, and Spring 2023 NASA History Space Grant Recipient

First of all, it is necessary to restart our lunar program and missions to other planets of the solar system as quickly as possible....

—Russian President Vladimir Putin[1]

ON 11 AUGUST 2023 at 8:10 a.m. local time, the Luna-25 lunar lander was launched atop a Soyuz-2.1b rocket from the Vostochny Cosmodrome, and on 19 August at 2:57 p.m. Moscow time, communications were lost as the spacecraft crashed into the lunar surface. Luna-25 had been planned to land at the Boguslawsky crater near the lunar south pole and spend the next year studying the plasma and dust components of the lunar polar exosphere and the composition of the polar regolith.[2] While its intended purpose may not stand out as unique among the lunar exploration missions currently being conducted by NASA, the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the Indian Space Research Organisation (ISRO), and the China National Space Administration (CNSA), Luna-25 was supposed to mark the first successful steps out of the starting gate for a post-Soviet planetary science program.

In 1976, when the Luna program last launched, the planetary science program was becoming the pride of the Soviet space program and establishing the Soviet Union's global leadership in space activities.[3] Searching for political victories after losing the race to put a man on the Moon, the Soviets succeeded in being the first to return lunar samples with a robotic mission (Luna-16), put a rover on the Moon (Lunokhod 1), land on Venus (Venera 7), and complete a soft landing on Mars (Mars 3). During this same period, NASA faced post-Apollo budget cuts and chose to prioritize crewed missions like Skylab and the Space Shuttle Program. The U.S. planetary science program fizzled; no planetary spacecraft were launched by the United States between 1978 and 1989. Uncontested, the Soviets kept pressing their advantage with robotic missions, leading to numerous historical "firsts" and political victories. The immense success of the Soviet Union's planetary science program during this period was due primarily to two factors: high risk tolerance and a resilient budget. Both of these factors were facilitated by extreme state secrecy. Missions were launched without notice and without stated goals. This allowed the Soviets to cover up launch failures or missions that never left low-Earth orbit, but it also allowed them to frame failed missions as successes, such as lost Mars orbiters reimagined as successful Mars flybys.[4] Importantly, this meant that the program never suffered domestic audience costs in terms of undermined prestige or budget cuts due to failed missions. In a way, this period was a precursor to the "faster, better, cheaper" approach that would come to define NASA's Discovery Program success; the Soviets could launch in nearly every launch window at artificial prices set by the Communist Party, who controlled the costs of natural resources, manufacturing, transport, and labor. It was a perfect recipe for persistently pursuing high-risk, high-scientific-reward missions. Wes Huntress, former NASA Associate Administrator for Space Science, has argued that "state secrecy concealed the fact that the Soviet robotic space exploration program was bolder, more innovative, and more tragic than any observers in the West could have imagined at the time."[5]

Mikhail Gorbachev's Glasnost (openness) ended the secrecy that facilitated high risk tolerance, and Perestroika (restructuring) changed the basic relationships between the government, society, and the Soviet economy. Launching costly rockets for propaganda victories was no longer an option. The newly structured space agency needed income to supplement a now-limited government budget, and they needed a model that could stand up not only to newfound public scrutiny but also to the scrutiny of paying international customers. Gorbachev set up Glavkosmos to attract commercial space business and coordinate with foreign organizations.[6] This new political and budgetary landscape was pressure-tested by the 1988 Phobos mission. Phobos 1 and 2 were highly international projects—they intended to carry 24 experiments provided by 15 different countries to Phobos, the larger of Mars's two moons. The launch was attended by the international press, a group of international scientists working on the mission, and a U.S. military delegation. Advertising space on the side of the rocket was even sold to Italian and Austrian steel companies. It was a devastating failure when communication with Phobos 1 was lost en route due to a human coding error and Phobos 2 failed in orbit. Turmoil followed. Long-held tolerance for failure in pursuit of bold initiatives collapsed in the face of international embarrassment. The program was exposed to domestic and international scrutiny for the first time, and severe budget cuts were handed down in 1989.

The newly structured space agency needed income to supplement a now-limited government budget, and they needed a model that could stand up not only to newfound public scrutiny but also to the scrutiny of paying international customers.

The planetary science program encountered even greater challenges while navigating the dissolution of the Soviet Union. Planning had begun in 1989 for another international attempt on Mars (Mars 94), though the financial picture was already bleak. The Soviets did not allocate any initial funding for the project. France and Germany agreed to contribute investigations totaling more than $120 million, but funding from the Soviet government arrived slowly and in small amounts. Instruments were deleted, and the mission was significantly simplified from initial designs. When the USSR collapsed, financing problems became acute. For the first time in the history of the Soviet planetary science program, money became a pacing issue: the project faced fits and starts as funding from the government and parts from contractors failed to arrive. In late 1993, the fledgling Russian Space Agency was forced to ask partners for funding to keep the project afloat, leading to an additional $10 million from France and Germany. There were water and power shortages at the Baikonur launch facility as bills to the now-independent Kazakh authorities went unpaid.[7] The situation became so dire that tracking ships were recalled to port and most were sold off.[8] When Mars 94 finally launched as Mars 96, it suffered a catastrophic launch failure. Because there were no tracking ships in the Pacific, there was a lack of telemetry data during critical moments of the escape phase, precluding identification of the cause of the failure. Mars 96 was a death knell for the Soviet planetary science program.

But persistence is the key character trait of the Russian space program. As early as 1997, the newly formed Russian

Space Agency began initial plans for Luna-25, known then as the Luna-Glob Moon exploration program. The 1998 financial crisis put the program on ice until the Russian Space Agency, now reorganized as Roscosmos, attempted to revitalize it as a joint 2004 project with JAXA known as Lunar-A. That project faced technical delays and was canceled in 2007. Immediately following the cancellation of Lunar-A, Roscosmos signed an agreement with ISRO to redevelop Luna-Glob as the Chandrayaan-2 lunar lander. In 2012, there was a significant delay in the construction of Chandrayaan-2 due to a launch failure of the joint Russian-Chinese Phobos-Grunt mission to Mars. The following year, ISRO backed out of the partnership and decided to develop Chandrayaan-2 independently. Russia's Mars woes continued in 2016, when a joint mission with ESA, ExoMars, was lost on descent. Future joint ExoMars missions were canceled by ESA in 2022 due to Russia's invasion of Ukraine. No missions to the Moon or Venus were launched during this tumultuous period. Despite successes in the human space program, most notably as a partner and reliable transit option to the International Space Station (ISS), Russia failed to get a post-Soviet planetary science program off the starting blocks.

Following the 2011 Phobos-Grunt failure and the cancellation of Chandrayaan-2, Roscosmos returned to independent development of the Luna-Glob program, now renamed Luna-25 to imply a connection to and continuation of the successful Soviet planetary science program. The program was initially planned to launch in 2012, only to be delayed on at least six separate occasions until its unsuccessful August 2023 journey. As NASA's Discovery Program reaches its 30th anniversary and celebrates numerous successes, the Russian planetary science program is once again experiencing false starts, this time with a project steeped in Soviet legacy and 25 years in the making. With the lessons of the successful Discovery and Soviet programs in mind, one may ask if the current iteration of the Russian planetary science program has conditions to facilitate similar successes. Three key factors are likely to limit Russia's prospects. First, despite a modest budget increase for Russian space-related activities from $2.7 billion to $3.1 billion in the next year, other projects like continued support of the ISS, development of a new Russian Orbital Service Station (ROSS), and military space activities are likely to take priority among limited resources. Second, the recent history of failed international partnerships, combined with the political fallout from the Russian invasion of Ukraine, are likely to limit partnership opportunities for future programs. Third, the very public competition for lunar real estate, Russia's lack of recent successes in planetary science, and a struggling wartime economy will surely heighten public scrutiny of failure. Despite those challenges, Roscosmos does have three crucial factors supporting the new program: a persistent and resilient space sector, supportive state leadership, and a population nostalgic for international prestige and Russian leadership in space exploration. In response to the failure of Luna-25, Director General of Roscosmos Yuriy Borisov simply stated that work should be stepped up on Luna-26 and Luna-27 to achieve the desired results.[9] Only time will tell if invoking the Luna program is a sufficient spark to rekindle Soviet success within a new, post-Soviet planetary science program. Either way, the Russians are sure to keep trying. ■

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Preserving MESSENGER's Journey from Day One

» By **Julie Pramis**, Summer 2023 Archives Intern, NASA Headquarters

NASA HEADQUARTERS Archives staff recently completed processing the MESSENGER collection donated by Dr. Sean C. Solomon, the mission's principal investigator (PI). MESSENGER stands for MErcury Surface, Space ENvironment, GEochemistry and Ranging—referencing the focus of this mission to capture data on the geology, magnetic field, and chemical composition of the terrestrial planet closest to the Sun. It was the first spacecraft to orbit Mercury and the first to fly by since Mariner 10 in 1975. On the way to Mercury, MESSENGER also did two flybys of Venus, which served as gravity-assist maneuvers and allowed the spacecraft to capture data on Earth's sister planet. These flybys were coordinated to share data with the European Space Agency's (ESA) Venus Express mission, which launched a little over a year after MESSENGER.

Looking at when records for the MESSENGER mission start, we must go back several years before its launch to the first proposal for a Mercury orbiter in 1996. And yes, I said "first proposal," because MESSENGER was not selected as a Discovery Program mission the first time around. MESSENGER reached the second round of reviews in 1997 but was considered high-risk, and NASA passed. For a spacecraft that travels close to the Sun, thermal design is critical. Not enough testing had been done up to that point to reassure the review panel that MESSENGER had the right solution to survive the heat. Additionally, the second round of reviews focused more on the technical, management, cost, and other factors (TMCO) rather than the science, which is where Dr. Solomon considered himself a "rookie PI" at the time. He and the team learned a lot from the Discovery review process (a rookie no more!). They took that feedback and hired Max Peterson as the project manager; Johns Hopkins University Applied Physics Laboratory (APL) tested the solar arrays extensively, and they re-proposed the next year.

Shortly after MESSENGER was selected, two major events affected future missions at NASA. First, the Mars Polar Lander was lost (likely crash-landed on Mars) in late 1999. Then, in 2002, NASA lost contact with CONTOUR (COmet Nucleus TOUR), the spacecraft intended to study the interior of at least two comets. The CONTOUR mission was also an APL mission, so it had overlap with MESSENGER on its subsystems and people who worked on them. These events led difficulties between the project and NASA Headquarters in the form of extra scrutiny and reviews in the early stages of MESSENGER.

The MESSENGER archival collection reflects that context, with many printed slide decks for the design reviews, site visits, meetings, and other presentations throughout the mission. Monthly and quarterly reviews cover nearly every month for six years—from 2006 to 2012. Records of attendance and presentations at national and

↑ The MESSENGER spacecraft lifts off early on 3 August 2004 from Cape Canaveral Space Force Station to begin its seven-year journey to Mercury. (Image credit: NASA)

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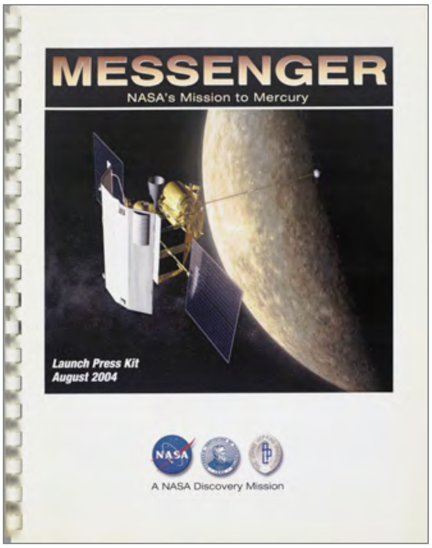
Preserving MESSENGER's Journey from Day One (continued)



MESSENGER's August 2004 launch press kit is one of the many records that make up the archive. (Image credit: NASA)

international conferences are plentiful. More than anything, though, e-mail correspondence throughout the mission (from planning in the early 1990s to active orbit through 2012) is well represented. Contained within nearly every folder, these e-mails add valuable context. Communication between the team members on everything from working on drafts to tracking news coverage of their work is documented in detail thanks to Dr. Solomon's dedication to preserving these messages.

E-mail archiving in the late 1990s and early 2000s was not what it is today, so having access to these e-mails in any form—even print-to-file—is a win for the NASA Archives. The day-to-day processes of planning a mission, writing a proposal, and tracking the mission from prelaunch to active orbit, plus all the educational and outreach work in between, cannot be captured in this level of detail without workaday records like e-mails, which we often take for granted. A portion of this correspondence is currently in the process of being digitized because they will be easier to search (and store) when they are back in digital form. (Archivist's note: Digitizing printed e-mails is not the same as e-mail archiving. There are digital tools available to preserve e-mails as they exist in digital form, but without access to the original born-digital records, re-digitizing printed e-mails is a good option.)

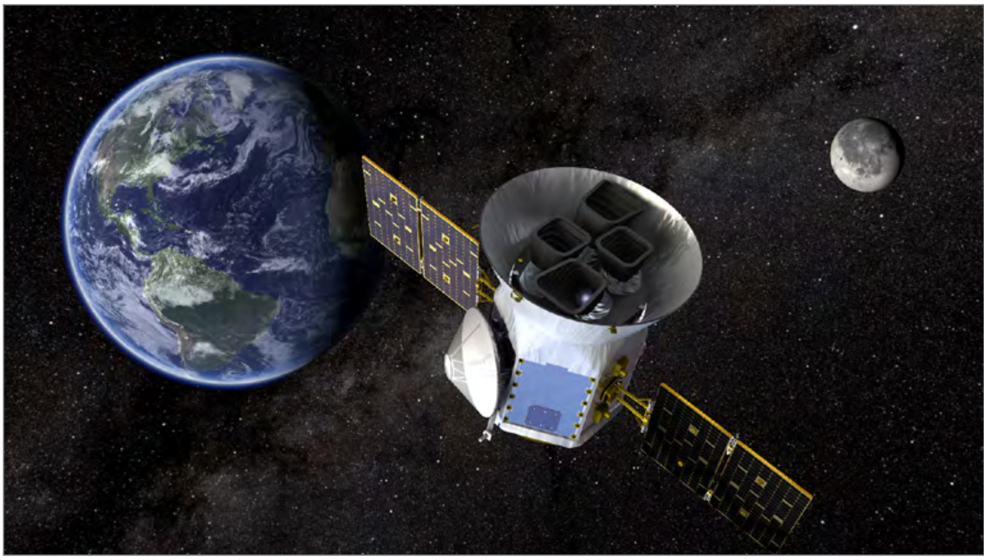
Another exciting part of this collection is evidence of its collaboration with BepiColombo, the international mission from ESA and JAXA to send two orbiters to Mercury. BepiColombo launched in 2018, a few years after MESSENGER concluded its mission, but planning started much earlier: four meetings and workshops between 2006 and 2012 with the MESSENGER team are captured in the collection. BepiColombo is currently en route to Mercury, on a mission to build our understanding of the planet's surface, internal composition, and magnetosphere!

A mission like MESSENGER, which had multiple proposals, extensions, collaborations, and close review from management, provides great insight into the processes of sending a spacecraft out into the solar system. Not only the science but the project management are captured in detail for the benefit of future missions. The materials are now arranged and described (from Dr. Solomon's already very nicely organized files), so MESSENGER's experiences can aid PIs and researchers well into the future. ■

In May 2011, a first-day-of-issue ceremony for Project Mercury and MESSENGER Mission commemorative stamps (left) took place at Kennedy Space Center's Visitor Complex. This program from the event (right) is part of the archive. (Image credit: NASA)

TESS: In Search of New Worlds

» By **Vaibhavi Mahajan**, Summer 2023 NASA History Intern



This artist's concept shows the TESS spacecraft in its highly elliptical orbit around Earth. (Image credit: NASA/GSFC)

FROM THE SCREENS of science fiction movies and the pages of books describing fantastical worlds, we have created images of planets outside our solar system. But what really exists out there? What exoplanets are close to us, and why is it important to find them—other than in search of extraterrestrial life?

Launched on 18 April 2018, NASA's Transiting Exoplanet Survey Satellite (TESS) aims to find out. Unlike previous missions in search of exoplanets, TESS has a broader definition of what types of exoplanets it is looking for. Using a wide-field camera to study a larger portion of the sky, the telescope looks for planets that are not just larger than or similar in size to Jupiter, but also smaller worlds closer in size to Earth. It also sets its sights on potential exoplanets orbiting stars that are within our galaxy, including stars visible to the naked eye.

TESS is not the first mission to search for exoplanets: while the Hubble and Spitzer Space Telescopes both made exoplanet observations, discovering these planets was not their main objective. It was not until March 2009, when NASA launched the Kepler space telescope, that the search really began. Kepler's main objective was to explore the structure and diversity of planetary systems—and it did. Surveying a specific region of the sky, Kepler observed more than 150,000 stars and found more than 2,600 planets beyond our solar system, some of which seem promising for harboring life because they exist in the habitable zones of their stars.[1] After almost a decade of success, Kepler was decommissioned in 2018, the same year TESS launched.

Like Kepler, TESS uses the transit method—where a dip in the brightness of a star signifies a planet passing in front of it—for detecting exoplanets. But TESS is distinct in using four wide-field charge-coupled device (CCD) cameras, giving it the ability to observe 75 percent of the sky during its primary mission—mapping the southern sky in its first year and the northern sky in its second.[2] Once every two weeks, the telescope collects data and sends them back to Earth.

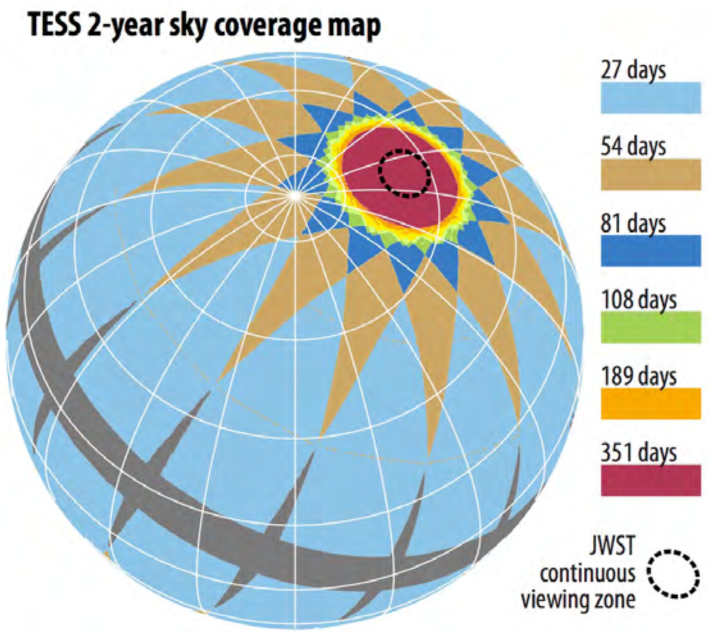
TESS's launch marked a milestone in exploring our universe, but building the telescope did not come without its challenges.

TESS's launch marked a milestone in exploring our universe, but building the telescope did not come without its challenges. Program Manager for TESS Jeff Volosin says that one of the biggest challenges was planning the mission with little knowledge of what was going to happen or what the telescope would find. Furthermore, the cameras on TESS were so sensitive that they could not risk accidental exposure to light, so scientists had to be extremely careful when working on them. NASA had never before attempted to launch something so sensitive.

"The launch was an unforgettable event," says Joshua Winn, who has served in many roles in the development of TESS, including as its Deputy Science Director. He is currently working on editing proposals to extend the mission. "It was surreal to see the rocket lift off after 12 years of anticipation." Like Volosin, Winn agrees that TESS's success did not come without challenges. He noted that after persisting through many years of uncertainty, the failure of the first NASA proposal was a large obstacle.

As of 6 September 2023, TESS had discovered 6,788 candidate exoplanets, of which 383 have been confirmed.[3] Among these thousands of potential exoplanets TESS has identified, what differentiates a candidate versus a confirmed exoplanet? Seeing a transit once is enough to label an exoplanet candidate, but not enough to confirm. Dips in the brightness of a star can also be due to star spots, eclipsing binaries, or stellar variability. The only way to truly confirm a potential exoplanet is by observing its transit at least twice and determining the periodic orbit of the planet. Not all exoplanets are readily confirmed; if a potential exoplanet takes 10 years to orbit its host star, TESS will not have captured more than one transit and it will remain a candidate exoplanet until it makes an additional transit.

Described as "The People's Telescope," TESS publishes its data for the public so anyone can take up the search for exoplanets.[4] In fact, almost all of TESS's confirmed exoplanets were found by someone other than scientists at NASA. Astronomer Paul Dalba attributes much of the success in finding exoplanets to citizen scientists and adds that the more people sift through TESS data, the better the chance there is of finding exoplanets. Still, more students and astronomers are needed to collect and work with the data. "It's a good problem to have, I suppose," Dalba says.



↑ In this diagram, TESS's observation segments for the first two years of operation are shown. In its first year, TESS observed 13 overlapping sectors in the sky's southern hemisphere and observed an additional 13 in the northern hemisphere in its second year.

Tom Jacobs belongs to an amateur and professional astronomer collaboration called the Visual Survey Group (VSG), formed in 2020, that works with TESS data. Using a light curve viewer, surveyors can scroll through TESS light curve data as fast as 1–3 seconds per light curve. So far, the VSG team has surveyed millions of TESS light curves to detect exoplanets. In collaboration with Dalba, the team confirmed exoplanet TOI 2180b, a gas giant that is 381 light-years away from Earth.[5]

When asked how it felt to find an exoplanet, Dalba said, "It's a novel feeling of exploring the unknown. Only a small fraction of humanity has had the immense privilege of discovering a planet, and it's an honor and a joy to join that club."

So, once you have found an exoplanet, what comes next? What if it does not show the potential for extraterrestrial life? Why do we still look for them? Jacobs says that while many people in the community say that the goal is to search for Earth-like planets and extraterrestrial life, the VSG thinks that all exoplanets add to our knowledge and catalogs all prospects, even though only a handful make it to scientific papers. "What we may not feel excited about today may likely be very exciting to future researchers with advanced technology," he says.

TESS: In Search of New Worlds (continued)

"Only a small fraction of humanity has had the immense privilege of discovering a planet, and it's an honor and a joy to join that club."

Exoplanets also provide a unique lens for understanding our own planet's formation as well as that of others in the universe. They provide a more expansive view of what planets exist in the universe compared with what we know from our own solar system alone. From worlds that are rocky and treacherous to worlds that are filled with noxious fumes, we have learned through TESS that planets in our universe can be completely different from those we already know.

TESS also helps us better understand other stellar phenomena. Volosin points out that TESS offers information about stellar evolution and supernova formation. Scientists can use TESS data to look back at stars before supernova events occur. The mission is also providing new data about comets, asteroids, and stellar variation in general.

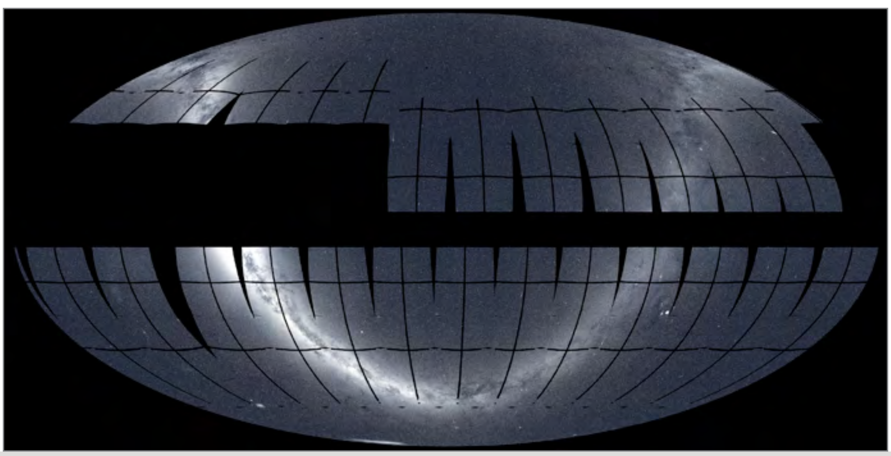
The James Webb Space Telescope takes TESS data and uses them to make followup observations of exoplanets.[6] Webb is not powerful enough to study the exoplanets of distant stars, so the TESS team designed their telescope to target nearby stars that were within the reach of Webb and other current and planned space telescopes.

The search for exoplanets does not end with TESS or Webb. Winn says that although the transit method is the current method for finding exoplanets, within five years astrometric data from the Gaia spacecraft and gravitational lensing data from the Nancy Grace Roman Space Telescope will lead to the discovery of hundreds, or even thousands, more exoplanets. Eventually, with the development of NASA's New World Explorer in coming decades, we may even be able to get direct images of Earth-sized planets.

With continued rapid innovations in technology, as well as collaboration of scientists across the globe, TESS is sure to discover more exoplanets in coming years and provide vital data for new missions.

For more on TESS and exoplanets, be sure to join us for **Joshua Winn**'s online presentation at noon on **11 October**. Information on how to join the meeting will be available from the NASA History list-serv.

↓ TESS's northern and southern mosaics are plotted to show the extent of its primary mission survey. The yearlong southern panorama (bottom) was completed in July 2019, and the northern imaging in July 2020. The prominent glowing band is the Milky Way, our galaxy, seen edgewise. (Image credit: NASA/MIT/TESS and Ethan Kruse [USRA])



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Thinking Outer Space

Astroculture and the Intellectual History of Planetarity

» By **Haitian Ma**, Lecturer in Film, Television, and/or Cross-Media Culture, Universiteit van Amsterdam

SINCE THE ADVENT of the Space Age, the thrill of escaping terrestrial bonds has been accompanied by an anxious glance back at Earth. This twofold conjuncture becomes increasingly polarized in the present moment. As renewed geopolitical competitions and privatized interest in space exploration continue, pressing concerns have been raised about the sustainability of the terrestrial environment. One popular motif in both undertakings, notably, is the portrayal of planet Earth in the universe, with all its mystery, beauty, and fragility. Yet this contemporary appeal to planetarity may find its foundations in centuries of thinking on outer space. The act of envisioning going into space, followed by the eventual realization of that vision, made humans see the world from a new lens—as a planet in the vast universe.

Probing this intellectual history of outer space and the concurrent process through which the world was turned into a planet in the minds of humans was the focus of the recent conference "Thinking Outer Space: Philosophy, Astroculture and the Histories of Planetarity," organized by Alexander Geppert (New York/Shanghai) and Rory Rowan (Dublin) and held at New York University (NYU), Berlin, from 19 to 21 July 2023.[1] Through nine thematically organized and chronologically arranged panels, 45 participants from all over the world examined the notion of planetarity—the thinking of Earth as a planet—from numerous historical lineages and philosophical contexts. The conference also facilitated exchange across disciplines, bringing together historians, geographers, anthropologists, literary scholars, political scientists, scholars of religion, and sociologists. The goal, as Geppert and Rowan pointed out, was to collectively develop a "canon" of space thinking across intellectual traditions and understand how space history and astroculture contribute to contemporary discussions around planetarity.

Intellectual Foundations

When did we start to perceive Earth in planetary terms? The presenters deromanticized conventional narratives that associated this process of "planetization" with the iconic Apollo *Earthrise* (1968) and *Blue Marble* (1972) images, pointing out the increasing portrayal of Earth in photographs since the 1940s, the establishment of satellite infrastructures, and concurrent development of Earth system science and environmental studies. Others traced the existence of planetary thinking to the work of early astronomers and geographers such as James Gall (1808–95) and Alexander von Humboldt (1769–1859). Apart from the technological, philosophical, and infrastructural aspects, a panel on "The Juridification of Outer Space" examined the role of law in shaping planetary imaginaries. One key marker was the proposition of "Metalaw" by American lawyer Andrew Haley in 1956, which upholds the principle of treating other beings the way

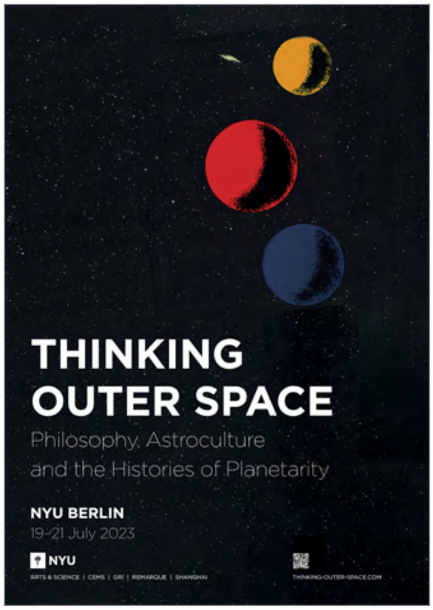
→ Alexander Geppert, co-convenor of the "Thinking Outer Space" conference, speaks during the Panel "A Planetary Turn?" at the NYU Berlin conference venue on 19 July 2023. Describing the recurrent visual icon of planet Earth in publications around global history, Geppert differentiated the process of "planetization" from that of "globalization," pointing out the intellectual lineage of the former back to the 1940s. (Image credit: Michèle Matetschk)

Thinking Outer Space (continued)

they desire to be treated rather than abiding by human frames of reference. Panelists explored how Metalaw and other related legal doctrines contested existing definitions of national sovereignty and advocated the utopian ideal of supranational order against the backdrop of the Cold War.

Astroculture

The three panels "Cosmic Philosophies," "Poetics of Planetization," and "Narrating Outer Space" addressed cultural manifestations of outer space and how they evoked different ways of relating to planet Earth. The subjects of inquiry ranged from public experiences of planetariums in the Weimar Republic, to the cyborgian thinking in 1950s American science fiction, to the autobiographical writings of contemporary Black astrophysicists and authors, to varied understandings of cosmism in present-day esoteric thought. In particular, panelists examined the constant mirroring between our imaginations of outer space and human responsibility to the planet. In a close reading of three modern Scandinavian writers—Harry Martinson (1904–78), Nils Mustelin (1931–2004), and Thorkild Bjørnvig (1918–2004)—varying degrees of caution against dystopian aspects of spaceflight could be detected, which called on the public to reflect on environmental destruction on Earth due to human activities. In another presentation on the growing UFO debates in Europe and North America in the latter half of the 20th century, it was evident that humans not only had established a more intimate connection to outer space, but also had come to encounter their own vulnerability on an existential level. In juxtaposition, based on the cosmology of Buddhist modernist Alan Watts (1915–73), human knowledge



Poster for the "Thinking Outer Space" conference held at NYU Berlin, 19–21 July 2023.

of outer space already resides in the inner self and actually derives from an inner speculation. This inquiry into the human psyche was another shared manifestation of planetary thinking and was discussed by the participants.

Political Imaginaries

As much as it is a philosophical concept, the term "planetarity" also carries specific political agendas and ideologies. Such instances included how the doctrine of panpsychism was closely tied to European colonialism in the writing of German geographer Friedrich Ratzel (1844–1904) or how the concept of "Russian cosmism" was arguably invented in the 1970s with intentions of fashioning Soviet nationalism. Other presentations examined the way planetary thinking transformed disciplinary practices in the humanities and social sciences. Propositions were made to integrate planetarity into ethnographic methods, developing strategies that find relationality between human and nonhuman subjects in field research. New questions arose as to whether planetarism could challenge existing ideologies of neoliberalism and nationalism and lead to new political imaginaries. Drawing on works of Jean-François Lyotard and Carl Sagan, participants also speculated on a post-human future after the solar catastrophe and how to integrate this distant horizon into the study of human geography.

Through the three-day exchange, the conference conjured a rich set of analytical tools, schools of thought, and historical roots in understanding contemporary planetarity. In the concluding discussion, participants raised further points of inquiry that emerged from the panels, such as the biopolitical implications of humanity in face of the Anthropocene, the possible political backlashes from planetization, and the techno-industrial bases of spaceflight that gave form to planetary thinking. Overall, the breadth of subjects and contexts both globalized and provincialized the scope of astroculture beyond western-centric modes of knowledge production, thus expanding and troubling the aforementioned "canon" of space thought in the making. The concept of planetarity threads through the philosophical backbone of space history but is simultaneously transformed and reinterpreted by it. For space historians, how to unpack this complex entwinement remains an open task. ■

Endnote

1 See https://www.thinking-outer-space.com for more information, including the complete conference program, lineup of speakers, and abstracts of all presentations.

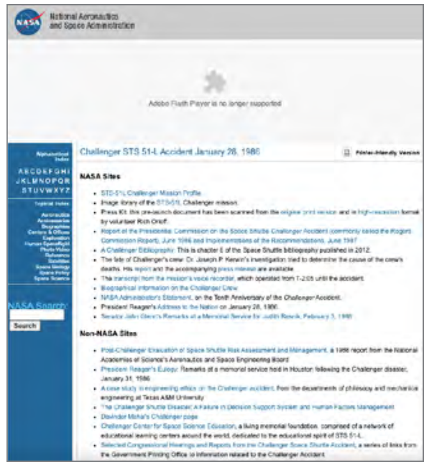
News from Around NASA

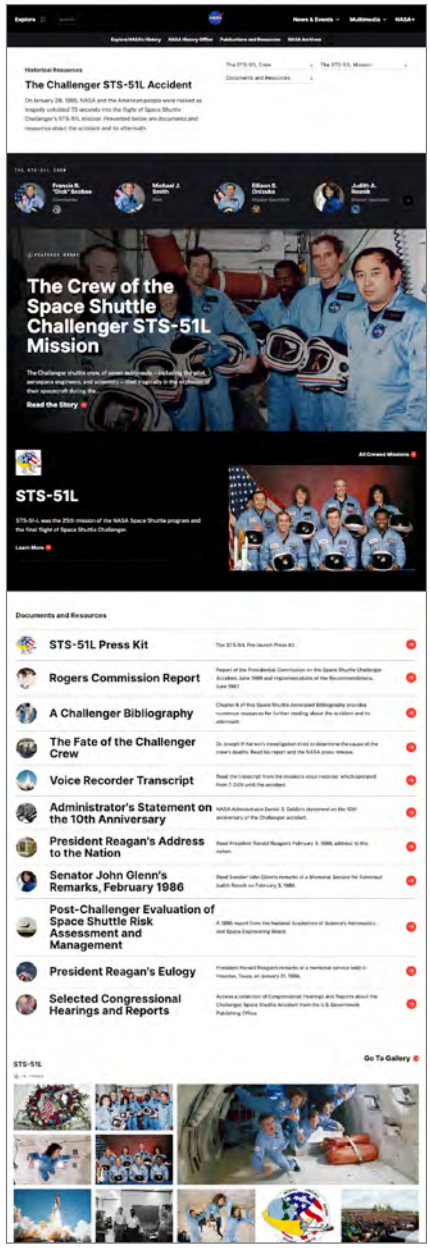
Rebuilding a Mountain: Adventures in Web Modernization

» By **Michele Ostovar**, Communications Specialist
and **Sandra Johnson**, Oral History Lead

ON 26 JULY, the world got its first look at a NASA project representing tens of thousands of hours of toil from a far-flung cadre of participants: not the launch of its newest space mission, but the beta release of the Agency's new website. The previous design, introduced in April 2015, was in sore need of a rehaul to deliver a more modern, streamlined, and visually compelling web experience. The goals for the new website included better accessibility for users with disabilities; more logical organization and navigation; improved integration of NASA's visual brand; more effective communication of NASA's value to the American public; and, by combining numerous comparable NASA sites, a more unified user experience. After NASA's new WordPress Content Management System (CMS) design was created and a strategy for the project developed, NASA and contractor staff embarked on building content starting in January 2023, and the effort continues as additional NASA websites are integrated.

NASA's History and Archives branch within the Agency's new History and Information Services Division kicked off the evaluation of existing content at https://history.nasa.gov, https://historycollection.jsc.nasa.gov, and https://www1.grc.nasa.gov/glenn-history/, as well as history articles and features within the www.nasa.gov domain, starting in early July 2022. With a new enterprise approach to the History and Archives branch operations, we reviewed relevant web content from each of the NASA Centers with the new goal of presenting a unified, streamlined, and centralized web presence. Next, the initial team turned to developing a plan for reorganizing and incorporating content into the new site and prioritizing the information to make sure our limited resources could accomplish the most essential building tasks by the scheduled launch date. Any user familiar with the material at https://history.nasa.gov can testify to its sprawling tangle of microsites, pages, and PDFs representing 30 years of additions. Metrics revealed that over 12,000 pages lived in the history.nasa.gov domain, most of which were rarely visited. Efforts centered on rebuilding the most-visited content and those resources central to the History and Archives branch functions, all with an eye to simplifying the user's experience while creating visually engaging web content. Some sections, like the NASA Archives content, were rebuilt from scratch, whereas some microsites were imported in their existing format until the content can be rebuilt in the new WordPress CMS.





→ Before and after: Historical resources about the STS-51L accident from https://history.nasa.gov/sts51l.html (top) and https://beta.nasa.gov/challenger-sts-51l-accident/ (bottom) are shown.

INTERN SPOTLIGHT

Vaibhavi Mahajan is a sophomore at Georgetown University studying science, technology, and international affairs in the School of Foreign Service. At the History Office this summer, she worked on a research article highlighting the important work of the TESS mission. (See her article in this issue.) She also helped with creating content highlighting aerospace anniversaries for NASA History's social media accounts.

Joshua Schmidt is currently on detail from the United States Forest Service to NASA's History Division. He grew up in Richmond, Virginia, and graduated from the University of Virginia with a bachelor of arts degree in history in 2012. Upon graduation, Joshua received his commission in the U.S. Navy and went through flight school in Pensacola, Florida, before spending the next 10 years as a helicopter pilot. Prior to leaving active duty, he received his master's degree in public administration and policy from American University and subsequently transitioned into the Presidential Management Fellowship program after separation. Joshua's work while on detail has primarily focused on early rotary aviation research performed under the direction of the National Advisory Committee for Aeronautics. Be sure to read his article in the summer 2023 edition of *News & Notes*!

Eleanor Drummond is a graduate student at the University of Maryland, working toward a dual master's degree in history and library science and specializing in environmental history and archives. During their work as a summer intern at Goddard Space Flight Center (GSFC) Archives, they digitized weekly reports made to the GSFC Director in 1989 and processed two collections: the Malcolm Niedner Collection, which contains records relating to cometary research in the 1980s, and the SMEX Collection, which contains photographs of the first five Small Explorer missions.

The majority of the NASA History and Archives staff are now trained to work in the new CMS and have been active contributors to rebuilding content in the new system. They have taken time out of their already-jam-packed days to build archives information, NASA Center histories, mission pages, and biographies; to migrate articles from the old site; to check history-related pages for accuracy; and to coordinate work with other participants at NASA Centers across the country. All this was done while the figurative plane was still being built: new modules, new content types, and new bugs appeared weekly as the project progressed.

With the official launch of the new www.nasa.gov planned for sometime in the coming weeks, the journey is not by any means over. The NASA History and Archives teams continue to add content and features. Most notably, a tool for users to search NASA's public archival holdings will be added. We also look forward to adding content from Johnson Space Center's History Portal, including over 1,300 oral history transcripts; building out new historical subtopic hubs; and incorporating engaging new modules, like timelines, quizzes, and other interactive features as these capabilities are brought online.

More than ever before, www.nasa.gov is becoming a powerful and engaging means of communicating NASA's history to the public and providing research opportunities and resources for researchers.

Visit the new NASA History and NASA Archives home pages on the beta site:

beta.nasa.gov/history/
beta.nasa.gov/archives/

If you see a problem or have a question, let us know!

NASA HISTORY OFFICE LUNCHTIME SPEAKERS

The NASA History Office invites you to attend these upcoming presentations on Microsoft Teams. Join our mailing list for event links.

20 September, noon ET
Cathy Lewis
"A Cultural View of Soviet and Russian Cosmonauts"

11 October, noon ET
Joshua Winn
"TESS and Exoplanets"

18 October, noon ET
Michael G. Smith
"Early Rocketry Education, the NACA, and Purdue University"

8 November, noon ET
Craig Gralley
"From NASA to NSA to STEM: The Pisgah Astronomical Research Institute"

29 November, noon ET
Alwin Cubasch
"Space Food for the Elderly"

13 December, 2 p.m. ET*
Hugh Slotten
"Global Satellite Communications"

* Please note the later time for this presentation.

Call for Papers: "NASA and Archaeology from Space"

A Symposium in Honor of Dr. Thomas L. Sever

18–19 September 2024 • Washington, DC

The organizers invite proposals for papers to be presented at a two-day symposium to be held in person 18–19 September 2024 in Washington, DC. We welcome diverse voices and perspectives to examine the history of NASA and archaeology from space.

The purpose of this symposium is to honor the pioneering work of former NASA archaeologist Dr. Thomas L. Sever in the field of archaeology and remote sensing over his many decades of service and numerous contributions. The symposium also seeks to provide insight and contextualization of past archaeology projects at NASA, highlight the current state of the field in terms of research and capabilities, and point to new opportunities in government and commercial sectors.

Potential topics include, but are not limited to, past archaeological projects, technology/capability developments, geopolitical considerations, assessments of the current state of remote sensing/archaeology, future trajectories, potential breakthroughs, and interdisciplinary approaches.

Presentations might also consider the impact of environmental, geopolitical, social, and cultural issues on archaeology/remote sensing projects over the decades and today.

The symposium will be a combination of panel discussions, keynote talks, and presentations on current NASA and industry capabilities. The intention is to publish an anthology of selected papers.

Submission Procedures

If you are interested in presenting, please send your presentation's title, an abstract of no more than 300 words, and a short biography or curriculum vitae, including affiliation, by 15 April 2024 to Brian C. Odom or Kelsey Herndon. Questions about the symposium are also welcome. ■

Learn more about Dr. Thomas Sever's archaeological research.

Other Aerospace History News

2023 Sacknoff Prize for Space History

Attention students: Your research paper could win a $500 prize! Since 2011, the Sacknoff Prize for Space History has been awarded annually to an undergraduate or graduate student for an original research paper in the field of space history—it could be a paper you wrote for a course! Winners receive the cash prize and will see their article published in the peer-reviewed journal *Quest: The History of Spaceflight Quarterly*. The deadline is **28 November 2023**. Learn more about the prize and how to submit your article at https://spacehistory101.com/space-history-resources/sacknoff-prize/.

Call for Applications for the Baruch S. Blumberg NASA/Library of Congress Chair in Astrobiology, Exploration, and Scientific Innovation

» By **Kevin Butterfield**, Director, John W. Kluge Center

As a partnership between NASA's Astrobiology Program and the Library of Congress, the Blumberg Chair, an annually selected position, supports an established scholar in the sciences, humanities, or social sciences to take up residence in the Library's John W. Kluge Center.

The Blumberg Chair creates an opportunity to use the Library's extensive collections to research the range and complexity of societal issues related to how life begins and evolves and to examine philosophical, religious, literary, ethical, legal, cultural, and other concerns arising from scientific research on the origin, evolution, and nature of life.

Within the parameters of NASA's mission, a chair might also seek to investigate how innovative quests for fundamental understanding may lead to major developments for the betterment of society. Barry Blumberg, for whom the chair is named, conducted groundbreaking research addressing a simple but fundamental question: Why do some people get sick while others, exposed to the same environment, remain healthy? That this work unexpectedly led to the discovery of the hepatitis B virus, the development of a vaccine, and the awarding of the Nobel Prize in Physiology or Medicine illustrates the potential for unconventional thinking about fundamental questions to yield great rewards. Using methodologies from the history and sociology of science; the philosophy of science; legal, political, and cultural history; and other disciplines, a Chair might study and tell the story of how a basic research initiative led to completely unexpected discoveries and applications.

Possibilities for research subjects are many and wide-ranging in scope. The following potential topics of research are meant to inspire, not limit, your creativity:

- Legal issues related to governance of planets and space
- "High risk, high reward" initiatives within the parameters of NASA's mission, from a historical, legal, philosophical, or ethical perspective or one that draws on several disciplinary modes of analysis
- Ethical implications of cross-contamination
- Scientific and philosophical definitions of life
- Conceptions of the origins of life in theistic and non-theistic religions
- Comparison of the discussion of these issues in multiple nations and cultures
- Life's collective future—for humans and other life, on Earth and beyond
- Impacts on life and future evolutionary trajectories that may result from both natural events and human-directed activities

Located in the Library's magnificent Jefferson Building, the Kluge Center offers a rich intellectual atmosphere for research, informal discussion, and exchange of perspectives.

Completed applications are due by 15 October 2023. For further information (including a new, streamlined process that does not require reference letters), please consult the Center's web page: https://www.loc.gov/programs/john-w-kluge-center/chairs-fellowships/chairs/blumberg-nasa-chair-in-astrobiology/.

Other Aerospace History News (continued)

American Astronautical Society (AAS) History Committee

» By **Michael Ciancone**, Chair

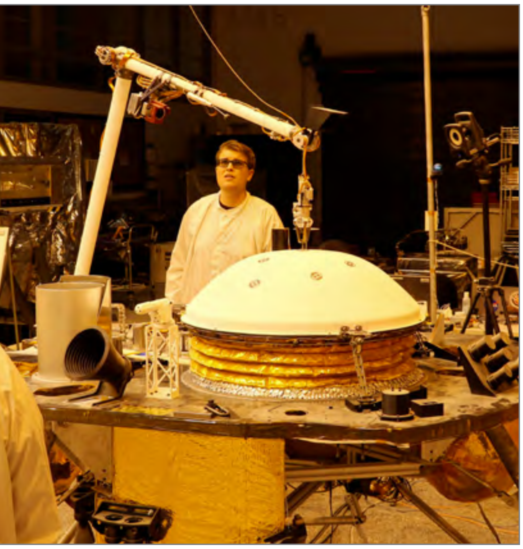
2022 Emme Award for Astronautical Literature

The Emme Award, named for NASA's first historian, recognizes outstanding books that advance public understanding of astronautics based on originality, scholarship, and readability. The Emme Award Panel, chaired by Dr. Don Elder, guided the review of submitted and solicited titles. Other members of the Panel are Dr. Rick Sturdevant and Dr. Jennifer Levasseur.

The Emme Award Panel has announced the following recipients:

Hugh R. Slotten, *Beyond Sputnik and the Space Race: The Origins of Global Satellite Communications* (Johns Hopkins University Press)

Honorable Mention: **Andy Saunders**, *Apollo Remastered: The Ultimate Photographic Record* (Black Dog & Leventhal)



2023 Ordway Award for Sustained Excellence in Spaceflight History

The Ordway Award is named in memory of Frederick I. Ordway III (1927–2014), human spaceflight advocate and chronicler of the history of rocketry and space travel. The award recognizes exceptional, sustained efforts to inform and educate on spaceflight and its history through one or more media, such as (1) writing, editing, or publishing; (2) preparation and/or presentation of exhibits; or (3) production for distribution through film, television, art, or other non-print media. The award is managed by the Ordway Panel of the AAS History Committee. Members of the Panel are Michael Ciancone (Chair), Robert Godwin, Dr. Valerie Neal, Ron Miller, and Andrew Chaikin (2022 recipient).

The Ordway Award Panel has announced the following recipients:

Dr. David Livingston is recognized for his steadfast and sustained efforts to raise public awareness of spaceflight history and current affairs as creator and host of "The Space Show" for more than two decades.

Marcia Dunn is recognized for her long career as an aerospace journalist covering the space beat for the Associated Press and providing timely, detailed, and accurate accounts of space history as it happened.

NASA's InSight mission tested an engineering version of the spacecraft's robotic arm in a Mars-like environment at NASA's Jet Propulsion Laboratory in 2018. The test is being conducted under reddish "Mars lighting" to simulate activities on the Red Planet. (Image credit: NASA/JPL-Caltech)

Chris Gainor, Author of *Not Yet Imagined*, Receives the Royal Astronomical Society of Canada's Ken Chilton Prize

Established in 1977 in memory of amateur astronomer Ken Chilton, this prize is awarded for a specific piece of astronomical research or work carried out or published recently. Chris Gainor's book, *Not Yet Imagined: A Study of Hubble Space Telescope Operations*, documents the history of the Hubble Space Telescope from its launch through its first 30 years of operation in space. Focusing on the interactions among the general public, astronomers, engineers, government officials, and members of Congress, the book reveals the decision-making related to service missions that made the Hubble Space Telescope a model of supranational cooperation.

Dr. Christopher Gainor received the Ken Chilton Prize for his book *Not Yet Imagined: A Study of Hubble Space Telescope Operations*. (Image credit: NASA)

The book also covers the impact of the Hubble Space Telescope and the images it produces on the public's appreciation for the universe and how the Hubble Space Telescope has changed the way astronomy is done.

Dr. Gainor's book was published by NASA's History Office.

Upcoming Meetings

2–6 OCTOBER 2023
International Astronautical Congress 2023
Baku, Azerbaijan
https://www.iafastro.org/events/iac/iac-2023/

18–21 OCTOBER 2023
2023 Oral History Association Annual Meeting
Baltimore, Maryland
https://oralhistory.org/annual-meeting/

25–29 OCTOBER 2023
Society for the History of Technology Annual Meeting
Long Beach, California
https://www.historyoftechnology.org/annual-meeting/2023-shot-annual-meeting-october-2023-long-beach-california/

8–11 NOVEMBER 2023
Society for Social Studies of Science (4S) Annual Meeting
Honolulu, Hawaii
https://www.4sonline.org/meeting.php

9–12 NOVEMBER 2023
History of Science Society Annual Meeting
Portland, Oregon
https://hssonline.org/page/HSS23

4–7 JANUARY 2024
American Historical Association Annual Meeting
San Francisco, California
https://www.historians.org/annual-meeting

↑ The Mars Reconnaissance Orbiter's HiRISE instrument captured this image from Mars's northern latitudes two days after the winter solstice, when the Sun was just a few degrees above the horizon. Winter frost covers the colder, north-facing half of each of the sand dunes. The frost here is a mixture of carbon dioxide ice and water ice. (Image credit: NASA/JPL-Caltech/University of Arizona)

8–12 JANUARY 2024
American Institute of Aeronautics and Astronautics (AIAA) SciTech Forum
Orlando, Florida
https://www.aiaa.org/events-learning/event/2024/01/08/default-calendar/2024-aiaa-science-and-technology-forum-and-exposition-(aiaa-scitech-forum)

18–19 JANUARY 2024
Discovery@30, New Frontiers@20 Symposium
Washington, DC
https://www.nasa.gov/feature/call-for-papers-for-discovery30-new-frontiers20-symposium

NASA HISTORY NEWS&NOTES

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→ This mosaic of NEAR Shoemaker images, taken on 3 December 2000, provides an overview of the eastern part of the asteroid Eros's southern hemisphere. NEAR Shoemaker was the first spacecraft launched in NASA's Discovery Program. (Image credit: NASA/JPL/JHUAPL)

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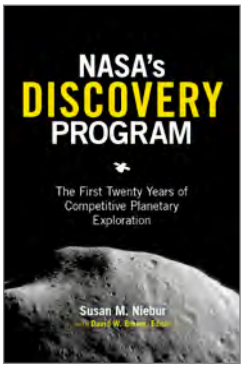
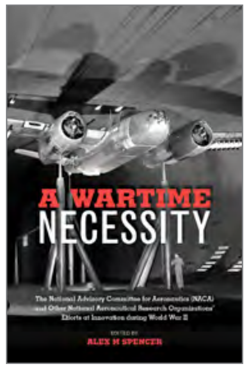


COMING SOON
NASA's Discovery Program
By Susan M. Niebur with David M. Brown (ed.)



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A Wartime Necessity
Edited by Alex M Spencer

NACA to NASA to Now
by Roger D. Launius

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