NEWS &NOTES

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OPPORTUNITY 2003–2018

THE SOCIAL MEDIA WORLD MEMORIALIZES THE ROBOTIC EXPLORER

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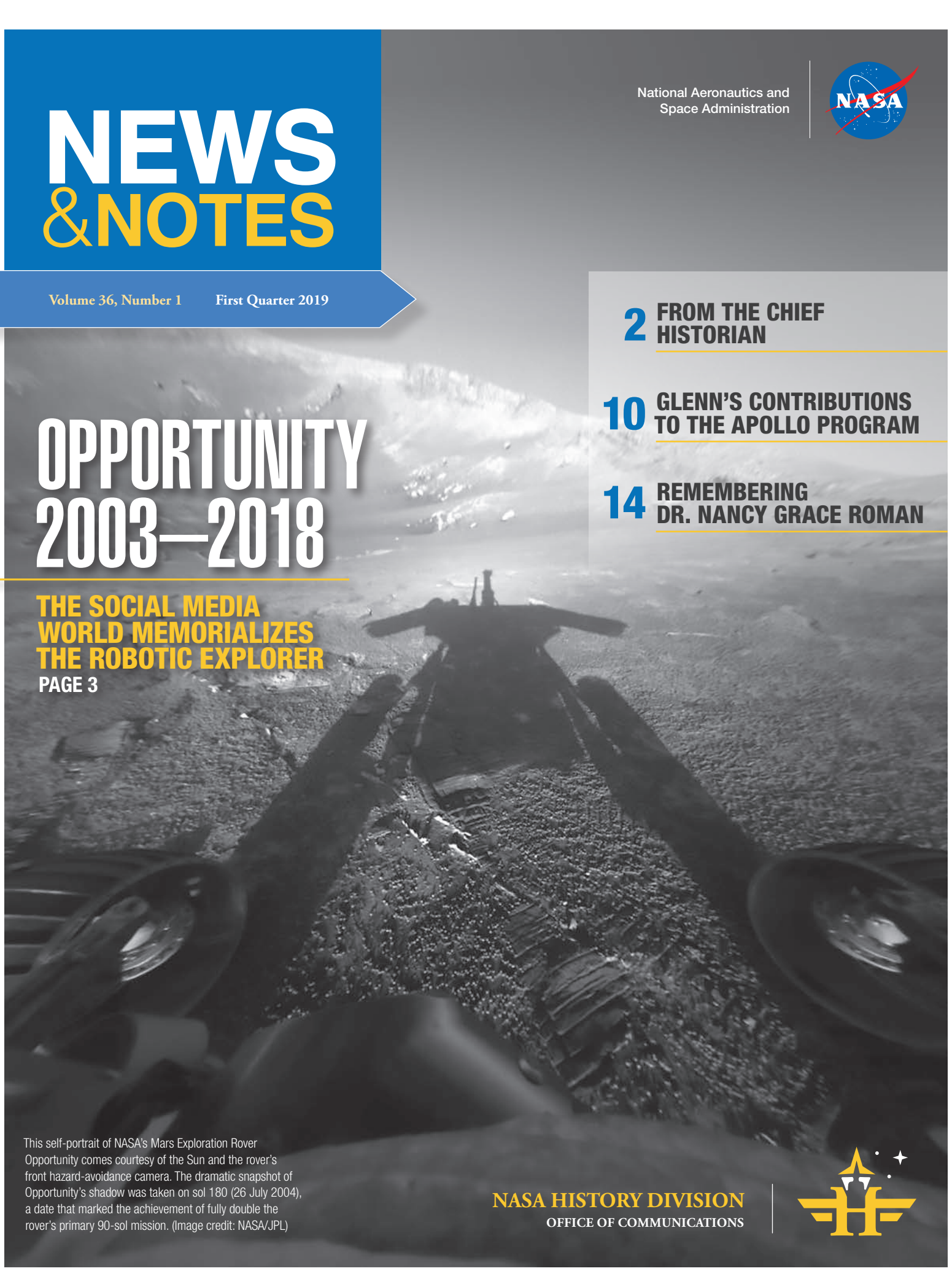


This self-portrait of NASA's Mars Exploration Rover Opportunity comes courtesy of the Sun and the rover's front hazard-avoidance camera. The dramatic snapshot of Opportunity's shadow was taken on sol 180 (26 July 2004), a date that marked the achievement of fully double the rover's primary 90-sol mission. (Image credit: NASA/JPL)

NASA HISTORY DIVISION
OFFICE OF COMMUNICATIONS

FROM THE CHIEF HISTORIAN

Welcome to 2019—the 50th anniversary year of the first human landing on the Moon! First, my apologies for the delay in our spring publication of *News & Notes*. We are still recovering from the extended shutdown of the U.S. government from late December to the end of January. Everyone in the Headquarters History Division was on furlough, and there were many time-critical tasks that did not get done. Right now, we are in a full-on sprint to get ready for the upcoming Apollo 50th anniversaries.

Although our lives are all about Apollo these days, we thought that we'd give you a break from that story in this issue and mark another important milestone with our cover story about the end of the Mars Rover Opportunity mission. In a case of real life echoing the movies (remember *The Martian*), a planet-wide dust storm brought the Energizer Bunny of planetary rovers to its end. My personal favorite memory of the Opportunity mission was the 2006 picture of Opportunity parked on the lip of the Victoria crater—an image taken by another of our Mars probes, the Mars Reconnaissance Orbiter. That we can have a probe in orbit around another planet taking a picture of our rover on the surface speaks volumes about the capabilities and depths of our planetary exploration programs. You can revel in the amazing statistics about Opportunity in our story, but I'll note here that such over-performance is not unusual at NASA. While NASA staff have faced their share of early mission failures over the years, a mission with success like the Mars Exploration Rovers does not seem all that surprising. Is this the result of outstanding engineering and excellent equipment? Certainly, at least in part. But, as we look at the Apollo program this year and consider the sweep of NASA history, I think it is clear that these sorts of successes rest on the dedication of an amazing workforce. You'll pardon my pride at having the chance to be involved in chronicling the history of these amazing people for future generations. And that swallowing sound you hear? That's me choking down some humble pie as I compare our furlough problems with the challenges faced, and vanquished, by my fellow NASA employees, both past and present.

> "YOU CAN REVEL IN THE AMAZING STATISTICS ABOUT OPPORTUNITY IN OUR STORY, BUT I'LL NOTE HERE THAT SUCH OVER-PERFORMANCE IS NOT UNUSUAL AT NASA."

Godspeed,

Bill

William P. Barry
Chief Historian

IN THIS ISSUE:

FEATURE

GOODBYE, ROBOT: HOW THE SOCIAL MEDIA WORLD MOURNED OPPY

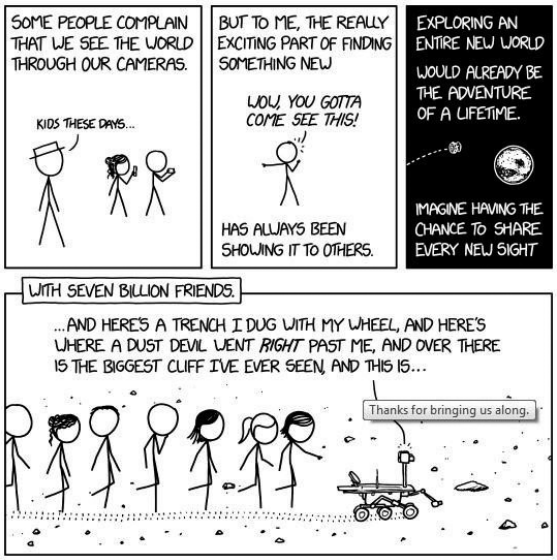
By Andres Almeida, Editor, NASA Headquarters

The world said goodbye to a trailblazing explorer on 13 February 2019 when NASA announced that the Mars Exploration Rover Opportunity had concluded its mission. The rover stopped communicating with Earth on 10 June 2018 after a severe Mars-wide dust storm blocked out the Sun and blanketed its location. After sending more than a thousand commands to restore contact, engineers in the Space Flight Operations Facility at NASA's Jet Propulsion Laboratory (JPL) made their last attempt to revive Opportunity on Tuesday, 12 February, to no avail.

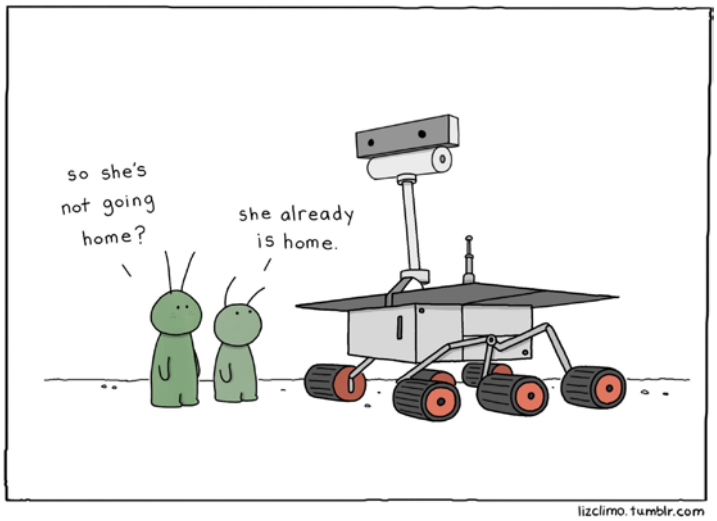
Designed to last just 90 Martian days, or sols, the persevering rover (affectionately known as Oppy) exceeded its life expectancy 60 times over. Nearly 15 years of Oppy's interplanetary exploration helped us better understand Mars and laid the groundwork for our return to the Red Planet. Although the mission concluded quietly, the public response was anything but quiet.

Tributes, homages, and anecdotes poured in. Webcomics from The Oatmeal, XKCD, and other illustrators inundated social media, anthropomorphizing the little rover and, in many instances, assigning it a blissfully ignorant Boy Scout–like persona. Anybody searching the hashtag *#ThanksOppy*, initiated by the NASA public affairs team, can find tributes galore.

We saw a similar reaction happen in September 2017 when the Cassini spacecraft concluded its extraordinary mission. There are some key differences to note in the way the public mourned: We knew Cassini was going to conclude; it had an end date, and it received an appropriately drawn-out farewell, giving us all a chance to appreciate the stunning science and spectacular imagery it had given us over the years; and the mission's elegant demise was even given its own title, Grand Finale. Nobody wanted the mission to end, but

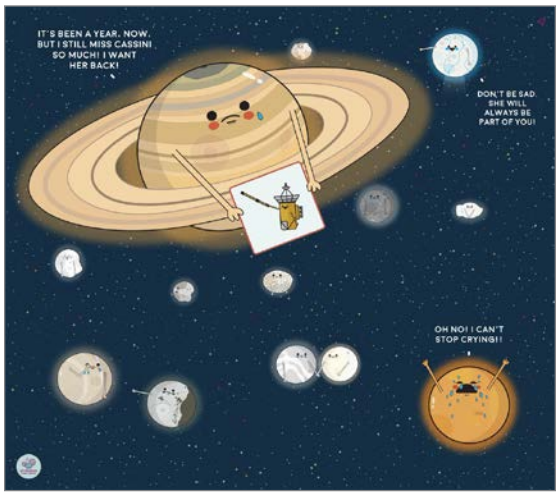


Opportunity guides a tour group visiting its exploration site. Notice the alt text that reads, "Thanks for bringing us along." (Image credit: XKCD)



Two Martian aliens stand in front of Opportunity. One wonders whether it is "going home," and the other replies, "She already is home." (Image credit: Liz Climo)

This @MarsRovers end-of-mission post received more than 39,000 retweets and 106,000 likes, making it one of the Agency's most popular posts. (Image credit: NASA)



This comic was released in 2018 for the first anniversary of Cassini's final dive into Saturn's atmosphere. (Image credit: Chiara Capuano)

it went out with grace, diving into Saturn's atmosphere to become part of the planet. Even today people are designing comics and memes that pay homage to the remarkable probe.

According to Sarah Loff, Digital and Social Media Supervisor at NASA Headquarters, Cassini's 2017 Grand Finale was a far bigger event by every other metric (live audience, reach of NASA's own social posts, and Web traffic). Nonetheless, Opportunity, with 548,000 social media mentions, surpassed Cassini's 545,000 mentions. As of 5 March 2019, the @MarsRovers end-of-mission post was the number 7 highest-engagement Facebook or Twitter post by *any* NASA account in the previous 365 days. The others are either to or about famous people or from the InSight landing.

Some people remember when the Mars Exploration Rovers landed. In fact, one of my favorite memories of my *abuelita* involves Opportunity. I remember coming home from my high school and greeting her at my house. As usual, we talked about our day, and she described how she saw on the news that another rover had landed on Mars. She must have seen an animation of the rover's deployment because of how she used her hands to mimic the opening of the ramp. Gesturing with her hands, she said it looked like a beautiful flower, letting the word "flower" (*flor* in Spanish) flow slowly. Like many around the world, she was enthralled. I was, too.

Prior to Oppy's final moments, the rover relayed a message to engineers that warned of its depleting battery supply. In an interview, one of the mission engineers loosely translated Oppy's signal as "My battery is low and it's getting dark." Some people took this literally, thinking that the rover itself had beamed back those exact words. Naturally, it spread like a social media wildfire, showing how we tend to anthropomorphize robots.

This apparent grieving of Oppy resembled that of another famous pop-culture robot, WALL·E from the Disney/Pixar film of the same name. In the movie,

WALL·E goes through the classic emotions: love, joy, frustration, anger, etc. Humans tend to ascribe human emotions to other creatures and insentient objects. Maybe this is how we cope.

Thomas Zurbuchen, Associate Administrator for NASA's Science Mission Directorate, said, "Whatever loss we feel now must be tempered with the knowledge that the legacy of Opportunity continues…."

"WHATEVER LOSS WE FEEL NOW MUST BE TEMPERED WITH THE KNOWLEDGE THAT THE LEGACY OF OPPORTUNITY CONTINUES…."

Of course, another way humans tend to cope with loss is with music. The final song engineers played for Oppy? "I'll Be Seeing You," popularized in 1944 by Bing Crosby and then Billie Holiday. It ends with these lines:

> I'll find you
> In the morning Sun,
> And when the night is new,
> I'll be looking at the Moon,
> But I'll be seeing you.

On reading about the song played for Oppy, Ella Cerón writes:

> Reader, I cried. I bawled my eyes out, over a robot I have never met. I considered watching *The Notebook*, a film that also uses "I'll Be Seeing You" to drive home the point that the people we love never really leave us, even after dementia and/or death. And where do we go from here, after knowing that robots can feel, and breakup texts reach Mars, and that not only could the red planet possibly sustain life, but bring on these emotions, too?[1]

Even though we were forced to say goodbye to Oppy and its twin rover Spirit, they are forever part of Mars. Perhaps one day humanity will reunite with these robotic explorers and say, "Thank you." As our Administrator, Jim Bridenstine, eloquently noted, "It is because of trailblazing missions such as Opportunity that there will come a day when our brave astronauts walk on the surface of Mars. And when that day arrives, some portion of that first footprint will be owned by the men and women of Opportunity, and a little rover that defied the odds and did so much in the name of exploration."

Opportunity landed in the Meridiani Planum region of Mars on 24 January 2004, seven months after its launch from Cape Canaveral Air Force Station in Florida. Its twin rover, Spirit, had landed 20 days earlier in the 103-mile-wide (166-kilometer-wide) Gusev Crater on the other side of Mars. Spirit logged almost 5 miles (8 kilometers) before its mission wrapped up in May 2011.

1 Ella Cerón, "This Dead Robot Taught Me How To Feel," *The Cut* (15 February 2019), ***https://www.thecut.com/2019/02/nasa-sends-mars-rover-final-message-with-billie-holiday-song.html*** (accessed 24 April 2019).

NEWS FROM HEADQUARTERS AND THE CENTERS

NASA HEADQUARTERS

Washington, DC

By Bill Barry

Looking back at the December *News & Notes*, it feels as if that was written in a different time-space continuum. There have been so many things happening in the last quarter—but let's start with some good personnel news. Thanks to funding from the Science Mission Directorate, we have hired an additional new archivist, Craig Haibon. Coming to us from the National Archives, Craig is here in a one-year position to help the Planetary Sciences Division of the Science Mission Directorate deal with some thorny archival questions related to the Regional Planetary Information Facilities (RPIFs). He has hit the ground running and is a most welcome addition to our archival team. Another important personnel change is that just before the government shutdown began, Administrator Bridenstine appointed Bettina Inclán as the Associate Administrator for Communications. Her enthusiasm for all things NASA (including our history) has been a pleasant boost in some challenging times early this year. One other significant personnel development this spring has been the lack of interns. We had a limited number of qualified applicants for the spring "semester," and the person who got the internship offer also got a better offer (and wisely took that) in early December. While the intern-free spring was not planned, it was probably a good thing that we didn't have a college student (or two) joining the rest of us on furlough at the start of the year. We had our usual stellar crop of applicants for summer 2019 and have selected Gwendolyn Rak (a rising sophomore at Swarthmore) and Claire Smrt (a rising junior at the University of Missouri). They will both be starting near the end of May and be with us into August to help with the busy Apollo anniversary season.

Some of you may have seen the NASA Inspector General's "Audit of NASA's Historic Property" (Report No. IG-19-002). The audit finds fault with a number of issues related to historic buildings and equipment. While the History and Archival programs were not directly criticized in the audit, the NASA response to the audit will involve our programs. One of the commitments made in response to the audit is to fill in the process gap in dealing with "heritage assets" that are not buildings. (The Historic Preservation Officer in the Office of Strategic Infrastructure is charged under the National Historic Preservation Act with issues related to historic "real property," i.e., buildings.) The history and archival programs are part of the team involved in creating (and probably implementing) the processes needed to fix the problems identified by the Inspector General. This is a work in progress.

Complicating the procedural answer to the Inspector General report, and making life more "interesting" in a number of ways, is the Mission Support Future Architecture Program (strangely acronymed as "MAP"). Based on a senior management decision in 2017, the Agency is doing a phased plan to evaluate and realign the NASA mission support bureaucracy with an eye to improved efficiency and better mission focus. The Office of Communications (the home of the Headquarters History Division) was originally scheduled to be "MAPped" at the tail end of the process in a couple of years. But this schedule was changed, and the Office of Communications (and hence the History Program) is scheduled to complete the MAP review and planning by the end of this fiscal year. Given that history and archival programs across the Agency are organized in a variety of bureaucratic stovepipes at various Centers, this will make the expected rationalization under MAP a very complicated problem. It is unfortunate that this extremely important initiative is coming just as the Apollo 50th anniversary season is upon us. Nonetheless, this is an important opportunity to tackle some of the challenges facing the Agency-wide history and archival efforts.

Later this spring, historians and archivists from across NASA will be meeting for our annual History Program Review and Training. This year, we'll be at Armstrong Flight Research Center from 7 May through 9 May. We will, of course, be discussing the response to that Inspector General audit, the MAP efforts, and the Apollo anniversary plans. It will be an extremely busy couple of days, but we are also looking forward to having our Review in such a historically significant location.

While the items above involve major new efforts, we continue to push ahead with the usual work of the History Division. This includes all of the normal day-to-day archival work, budget drills, inquiries to be answered, and our publication efforts. We have a number of exciting projects in the publication pipeline, but keep an eye out for *Origins of 21st-Century Space Travel* by Glen Asner and Steve Garber. This study of NASA's Decadal Planning Team and the Vision for Space Exploration is at the printer as I write this and should be available in print and for download very soon.

GODDARD SPACE FLIGHT CENTER (GSFC)

Greenbelt, Maryland

By Christine Stevens and Holly McIntyre

Building an archives program from the ground up usually means that there is an institutional need to preserve and provide access to a collection of significant material. In the case of Goddard Space Flight Center, the need had been voiced loud and clear across generations of Goddardites over the years. But while the need was here on Center, a centralized collection of historic material was not! The Goddard Archives is working to build that collection by identifying historically significant material across six field sites and 60 years of history. After we identify materials that may be of interest for preservation on Center, we employ the archival function of "appraisal" to determine what this material is, why it may or may not be significant, and whether it fits into the Archives' collection policy to be preserved on Center in perpetuity. But where do we get these materials? The Goddard Archives conducts appraisals on Center in employees' offices, in on- and off-Center treasure troves (storage closets), and in retirees' homes.

A great example of an off-site appraisal visit for a retiree was this past spring at the Dr. Paul D. Lowman, Jr., estate. In 1959, Paul Lowman was the first geologist hired by NASA, and he worked at Goddard in Greenbelt for over 50 years. Dr. Lowman, who resided in Bowie, was known for riding his bike to work and for his numerous publications and contributions to NASA. He passed away in 2011.

"A GREAT EXAMPLE OF AN OFF-SITE APPRAISAL VISIT FOR A RETIREE WAS THIS PAST SPRING AT THE DR. PAUL D. LOWMAN, JR., ESTATE. IN 1959, PAUL LOWMAN WAS THE FIRST GEOLOGIST HIRED BY NASA, AND HE WORKED AT GODDARD IN GREENBELT FOR OVER 50 YEARS."

We arrived at the estate on a cold February day and got to work. The entire home was full of NASA material, so we decided to divide and conquer. Two of us started in the office while the other two started in the basement. To help us make order out of chaos, we started by making piles of like subjects. Being a geologist, Dr. Lowman had a variety of rock samples, maps, photographs, and reports. These records were sorted based on what project they were related to. Dr. Lowman worked on pre-Apollo lunar geology projects, Apollo, Gemini, Spaceborne Imaging Radar (SIR), Landsat, and others. In the office, we found almost 100 small journals from 1959 through 2001 filled with meeting minutes, to-do lists, and ideas. We thought

that these journals would be a great addition to the archives because they show what daily life was like at Goddard during those years and provide great insight into cultural and organizational shifts over time. The home also contained a number of items of personal correspondence and ephemera such as Dr. Lowman's high school yearbooks filled with messages from his classmates and correspondence with NASA officials as he was looking for employment after college. His completed federal employment application shows that he was eager to join the Agency.

In the basement, there were filing cabinets full of working files and correspondence. Dr. Lowman kept most of his incoming letters and carbon copies of his outgoing letters from 1960 through 1995. Thirty-five years of correspondence paints a great picture of his life, the work he did, and how Goddard has changed over the years. Some of the correspondence folders, since they had been sitting in a filing cabinet for so long, had dirt and particulates in the folder. Moldy or dirty records should not come into contact with clean records as there is a risk for contamination. However, we did not have a quarantine space available to bring these records back to GSFC, so we needed to clean them before we brought them into the archives. On our last visit to the estate, we set up a plastic tarp in the driveway to clean the records with soft brushes. Wearing N-95 masks and gloves, we formed an assembly line and cleaned the dirty records before putting them into clean Federal Records Center (FRC) boxes.

Six weeks and multiple visits later, we had finally brought all of the Lowman records back on Center, where they were to be processed and preserved for years to come.

JOHNSON SPACE CENTER (JSC)

Houston, Texas

By John Uri

The JSC History Portal was relocated to a new Web address: *https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/*. We encourage everyone to update their bookmarks and also to help us in any way possible to advertise the new address. We are continuing efforts to upgrade the look and feel of the History Portal, and the changes will provide the History Office with easier control over content updates as well as a more modern format.

We continue to expand our extensive oral history collection. Jennifer Ross-Nazzal and Sandra Johnson completed interview series with several key NASA leaders: Lesa Roe, Robert Lightfoot, Mike Hawes, and Scott Hubbard. They also interviewed Poppy Northcutt, one of the first women to work in Mission Control, and former Naval Research Laboratory and Goddard engineer Edmund Habib. And while the partial government shutdown caused several interviews to be rescheduled, it gave Jennifer and Sandra time to process most of the backlogged interview transcripts, which will be uploaded to the JSC History Portal once the subjects have approved them for release.

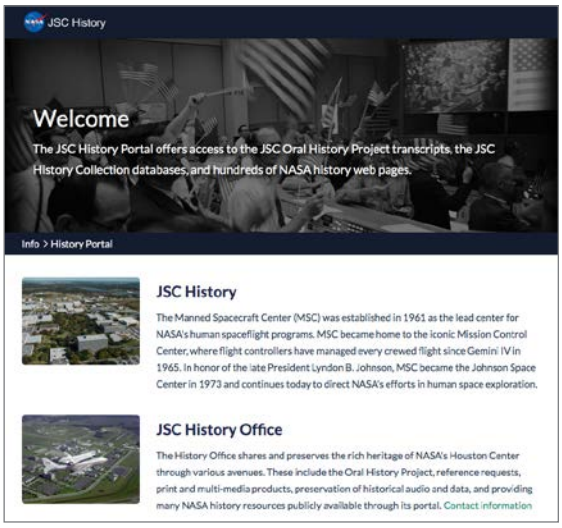
Sandra responded to a series of ongoing requests for oral history audio and video from filmmakers working on projects related to upcoming Apollo anniversaries. Of note were the following:

- A request from C-SPAN's American History TV for five video interviews conducted between 1997 and 2000 covering the Apollo 7 and 8 missions. The interviews were broadcast on C-SPAN3 in December and January and are available online. Sandra worked with the JSC Moving Imagery archive to digitize and provide the requested interviews.

- A request from BBC Radio for audio from NASA individuals involved in Apollo 8. Sandra provided audio clips of the requested oral history interviews.

- A request from the Smithsonian Channel for a six-part documentary series on Apollo.

- A request from the History Channel for a documentary on the 50th anniversary of Apollo 11.



JSC's history portal has been relocated to a new URL: *https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/*.

- A request for the British National Space Center exhibition about the former Avro project engineers who moved to Houston during the early days of NASA to work on the first spaceflight programs. (We did a series of interviews with those gentlemen early on in the project.)

- A request from the Johnsville Centrifuge and Science Museum for the video oral history interview with Betty Skelton, an aviatrix and aerobatics pilot who set 17 aviation and automobile records; helped create opportunities for women in aviation, auto racing, astronautics, and advertising; and, in 1959, was the first woman to undergo physical and psychological tests identical to those given to the Mercury Seven astronauts.

- A request for a previous oral history interview we conducted with Annie Easley, a former National Advisory Committee for Aeronautics (NACA) and NASA employee at Glenn Research Center. An article in Massive Science, an online science publication, relied heavily on this material. The article is available at ***https://massivesci.com/articles/annie-easley-facts-stem-mathematician-nasa-scientist-discrimination/***.

Along with several other NASA historians and archivists, Jennifer completed Records Management training provided by the National Archives and Records Administration (NARA). The NASA Chief Archivist, Robyn Rodgers, arranged the training for NASA History with the intent of creating a better partnership between history and records management programs. Because Jennifer completed all Knowledge Areas (Creating and Maintaining Agency Business Information, Records Scheduling, Records Schedule Implementation, Asset and Risk Management, and Records Management Program Development), she earned a certificate signed by the Archivist of the United States.

As our JSC Historian, Jennifer was featured as a guest on JSC's *Houston We Have a Podcast* (***https://www.nasa.gov/johnson/HWHAP/apollo-8-part-1***), and she participated in an interview with a film crew from Flair Productions, a French company, about Johnson Space Center and its facilities.

At the request of the NASA Chief Historian, Jennifer gave a keynote talk at the Apollo Dialogues Workshop held at the Smithsonian's Ripley Center. NASA's History Office and the Smithsonian Air and Space Museum sponsored the workshop. About 90 people attended the all-day event on 7 December 2018. Jennifer spoke about the importance of capturing and documenting women's contributions to the Apollo program. The talk was extremely well received, with many positive comments and offers of possible collaborations. At the end of the meeting, *First Man* screenwriter Josh Singer reintroduced himself to the historian and thanked her for her assistance with the film.

Jennifer gave a talk at Space Center Houston on 4 January 2019 on President Richard M. Nixon's decision to proceed with the Space Shuttle Program. On 15 February, she spoke about the decision to rename the Manned Spacecraft Center the Lyndon B. Johnson Space Center, to honor the late President for his contributions to NASA and to human spaceflight in particular.

In recognition of significant space anniversaries leading up to the Moon landing, the JSC History Office is working with the JSC External Relations Office on a continuing series of articles posted on the ***https://www.nasa.gov/topics/history/index.html*** Web site and JSC's Facebook and Twitter accounts. Abstracts of the articles appear online in JSC's *Roundup Today*. The Web articles were temporarily halted during the government shutdown, but they were posted after the government reopened. The missed social media posts were not recovered. The features often highlight the anniversaries of less-celebrated events and people that were nevertheless crucial to achieving the Moon landing within President Kennedy's timetable. Selected articles have also appeared as feature articles on the JSC Home Page's *Roundup Reads*. We would like to thank history and archive personnel at other NASA Centers for their valued help and contributions to many of these products.

The History Office continues its effort to publish Jennifer's book *Making Space for Women*, in collaboration with the JSC University Research, Collaboration and Partnership Office. The manuscript is currently undergoing peer review at Texas A&M University Press.

GLENN'S CONTRIBUTIONS TO THE APOLLO PROGRAM

By Bob Arrighi

The success of the Apollo 11 mission in July 1969 was based, in part, on NASA's decision in 1959 to utilize upper-stage vehicles fueled with liquid hydrogen. This determination stemmed from an effort that began a decade earlier at the NACA's Lewis Flight Propulsion Laboratory (today, Glenn Research Center) to transform the lightweight, high-energy hydrogen into a functional propellant. Lewis employees, both renowned and obscure, were among the thousands of individuals across the country who contributed to the Apollo Program 50 years ago. They transferred to Headquarters to help shape the Apollo program, resolved many technical issues involving each stage of the Saturn V, managed the vehicles that launched lunar exploration spacecraft, investigated the Apollo 1 and 13 accidents, and went on join the Apollo astronaut corps.

In the mid-1940s, a small contingent of Lewis researchers began studying small experimental rocket engines and the use of different highly reactive liquids as propellants. They intentionally avoided hydrogen since the military was then sponsoring hydrogen research at other institutions. In 1949, the Chief of Research, Abe Silverstein, expanded the rocket research. The group increasingly concentrated on hydrogen—which the military had by then forsaken. The effort steadily escalated and resulted in the successful flight tests of a liquid-hydrogen engine on a B-57 Canberra in early 1957. Representatives from Pratt & Whitney, which was developing its hydrogen-fueled RL-10 engine, frequently visited Lewis during this period. The RL-10s would power the Centaur rocket and serve as a template for Rocketdyne's J-2 engines, which were employed on the Saturn upper stages.

With the NACA's 1958 incorporation into the new space agency, numerous Lewis personnel, including Adelbert Tischler, Newell Sanders, Edgar Cortright, John Disher, and John Sloop, transferred to Headquarters to plan NASA's initial space missions. The two men with the most immediate impact on Apollo, however, were Silverstein and George Low. Silverstein was responsible for all of NASA's space activities during NASA's first three years and oversaw the Space Task Group's (STG's) human undertakings. Low served as the liaison between the STG and Headquarters.

In 1958, Silverstein served on a working group that proposed a multidecade spaceflight program that

included an eventual lunar landing. He also arranged for the transfer of Rocketdyne's 1.5-million-pound-thrust F-1 engine program from the Air Force to NASA. In December 1959, Silverstein chaired the Saturn Vehicle Team, referred to as the Silverstein Committee, to select vehicles for the Saturn Program, which the Army had recently transferred to NASA. Silverstein, who was intimately aware of Lewis's hydrogen work, convinced Wernher von Braun that Saturn's upper stages must use the high-energy liquid hydrogen.

In July 1960, Silverstein, who had named Project Mercury in 1958, designated the Moon mission as Apollo to continue the mythological naming precedent. At that point, NASA considered Apollo to be a human journey around the Moon that would lay the groundwork for future landings. Low, however, argued that the lunar landing should take precedence, and in October 1960, he obtained Silverstein's permission to establish a team to identify the options and requirements for such a mission. NASA presented their findings to Congress in February 1961. Although there was no immediate impact, two months later NASA officials, including Silverstein, used the Low committee's conclusions to respond to President Kennedy's request for a space mission capable of demonstrating the nation's technological superiority over the Soviet Union.

Shortly after the President announced the lunar mission on 25 May 1961, Lewis employees William Fleming and Bruce Lundin led separate committees that examined different staging and rendezvous methods for achieving this goal. The Agency initially assigned Lewis responsibility for the hydrogen propulsion system that would power the Lunar Module (LM), but the decision to employ a lunar rendezvous strategy negated the need for the large engine. In the fall of 1961, Silverstein returned to Cleveland to serve as Lewis Center Director. Low went on to lead the Apollo Spacecraft Program Office.

Meanwhile, researchers at Lewis continued efforts to resolve issues impacting hydrogen engines and the Saturn vehicle. Saturn's first stage (S-IC) was powered

Saturn I booster tests take place in the 8- by 6-foot supersonic wind tunnel at NASA Lewis Research Center (now Glenn). (Image credit: NASA)

by five massive kerosene-fueled F-1 engines that were experiencing combustion instability and turbopump pressure fluctuations. In 1962, Rocketdyne's consultation with Lewis fluids systems experts led to modifications that remedied the pump issue. Later that year, Lewis's Richard Priem tested different injector designs in the Rocket Engine Test Facility (RETF) and served on a team that troubleshot the instability problem. In 1964 and 1965, Lewis used a model of the S-IC in its two large supersonic wind tunnels to study the recirculation of the F-1 engines' hot exhaust. The tests provided important aerodynamic pressure data and determined the size of the actuators used to steer the engines.

During the early 1960s, Pratt & Whitney and Rocketdyne utilized Lewis's extensive experience with liquid hydrogen to guide them as they developed the RL-10 and J-2 engines. Lewis worked with the companies to resolve technical difficulties, particularly combustion instability. Lewis's testing of the RL-10 in the Propulsion Systems Laboratory (PSL) remedied a persistent screech problem, and extensive research at

the RETF led to the redesign of the concentric-tube injector used in both engines. In addition, Lewis researchers serving on a committee to review the J-2's turbopump issue were able to cite findings from their previous research that verified that the pump's inducer design would produce the desired pressure levels.

In the early 1960s, Lewis researchers used a drop tower, research aircraft, and sounding missiles to determine how fluids would behave in tanks operating in the low gravity of space. They found that the use of baffles within a tank kept the liquid in place and prevented sloshing when engines were cut off. In the mid-1960s, Lewis used its drop towers to calibrate and test the fluid management systems employed in Saturn's S-IVB stage and the Command and Service Module (CSM).

In 1964, Lewis tested a model of the CSM and its escape tower in the 8- by 6-Foot Supersonic Wind Tunnel. By testing the vehicle in simulated flight conditions at various angles, the researchers were able to predict the vehicle's aerodynamic stability with and without its control flaps deployed. There was also concern that the three large fuel cells that supplied the CSM with electric power would not operate properly in a microgravity environment. In 1965, Lewis's Michael Weinstein created a test loop that verified the performance of the system's condenser in low gravity and forecast the fuel cell's performance in a variety of conditions.

Lewis also contributed to the LM Ascent Engine, which used storable hypergolic propellants to launch the LM to rendezvous with the CSM. In 1967, Robert Dorsch and Leon Wentzel ran computer analyses of the engine's combustion instability and accurately predicted the vaporization rates of the bipropellants. Carl Aukerman and Arthur Trout tested the high-area-ratio nozzles used for the module's Ascent and Descent engines in the PSL. The program demonstrated that combustion instability in the hypergolics did not affect the nozzle performance and successfully forecast the engine performance during the Apollo landings. In addition, John Wanhainen served on a task group that resolved the Ascent Engine's combustion instability.

Scientists needed to study the surface of the Moon to identify optimal landing sites for Apollo. NASA employed a series of Lunar Orbiters to photograph the Moon from a distance, Rangers to send back data as they crashed into the surface, and Surveyors to land and analyze the soil. In 1962, Lewis was assigned responsibility for the Agena and Centaur upper stages used to transport these spacecraft. Between 1964 and 1967, Atlas-Agenas successfully sent four Rangers and five Lunar Orbiters to the Moon. However, Centaur, the first liquid-hydrogen-powered stage, required additional work. Lewis conducted an extensive four-year effort, which included seven developmental launches, to resolve Centaur's issues. Between 1966 and 1968, Atlas-Centaur vehicles successfully sent seven Surveyors to the lunar surface.

In 1967, Lewis's crash fire expert, Irving Pinkel, played a key role in establishing a timeline of events and determining the cause and behavior of the Apollo 1 fire. Pinkel and his co-investigators spent over a year afterward helping redesign the Apollo capsule and spacesuits. Four years later, Pinkel served as an official observer for the Apollo 13 investigation. The investigation was aided by tests in Lewis's Zero Gravity Facility that demonstrated that, contrary to previous belief, the capsule's Teflon-coated wires could burn in the low gravity of space.

Apollo astronauts Neil Armstrong and Fred Haise began their NASA careers as research pilots at Lewis before transferring to what was then the NASA Flight Research Center (later Dryden Flight Research Center and currently Armstrong Flight Research Center). In addition, Lewis pilots Joseph Algranti and Harold Ream became the instructor pilots for the Lunar Landing Training Vehicle (LLTV), and Warren North helped select several classes of Apollo astronauts and develop training programs for them.

Additional information on Glenn's contributions to the Apollo program can be found here: *https://www.nasa.gov/centers/glenn/about/history/apollew.html*.

OTHER AEROSPACE HISTORY NEWS

AMERICAN ASTRONAUTICAL SOCIETY (AAS) HISTORY COMMITTEE

By Michael Ciancone, Chair

Apollo 1 National Memorial

The Aerospace Industries Association (AIA) has requested support from the AAS History Committee in national efforts to create an Apollo 1 memorial at Arlington National Cemetery, as noted in the 2017 National Defense Authorization Act (NDAA). Dr. Don Elder is leading a special panel of the AAS History Committee to prepare a study on the "availability and suitability on alternative locations outside of Arlington National Cemetery." Panel members include Robert Pearlman and Michael Ciancone. A national memorial to the Apollo 1 crew will serve as a fitting tribute, some 50 years after their tragic deaths, from our nation to the three Apollo 1 crewmembers, who served their country in military uniform and at NASA. It will also recognize the importance of their sacrifice to the millions of Americans, including servicemen and -women, who supported NASA to make the triumph of the Apollo space program possible.

2019 Ordway Award for Sustained Excellence in Spaceflight History

The Ordway Selection Panel welcomes the addition of two of the 2018 recipients for the current award cycle: Dennis Jenkins and Miles O'Brien. Dennis and Miles join Valerie Neal, Rob Godwin, Ron Miller, and Michael Ciancone on the panel. This is a "rolling" award, so nominations are accepted at any time. Readers will find a link to the nomination form at the following Web site: *http://astronautical.org/awards/ordway/*

2018 Emme Award for Astronautical Literature

The Emme Award committee will begin contacting publishers of titles under consideration in April. The panel members anticipate a summer devoted to reading entries submitted for consideration. Dr. Don Elder chairs the Emme Selection Panel; other members are Dr. Rick Sturdevant, Dr. Asif Siddiqi, and Dr. De Witt Kilgore.

RICK MOORE HONORED BY OKLAHOMA HISTORICAL SOCIETY

By Bill Barry, Chief Historian, NASA History Division

Congratulations to Rick Moore on winning Outstanding Dissertation in Oklahoma History by the Oklahoma Historical Society. The annual awards luncheon was held in Chickasha at the University of Science and Arts of Oklahoma on 26 April 2019.

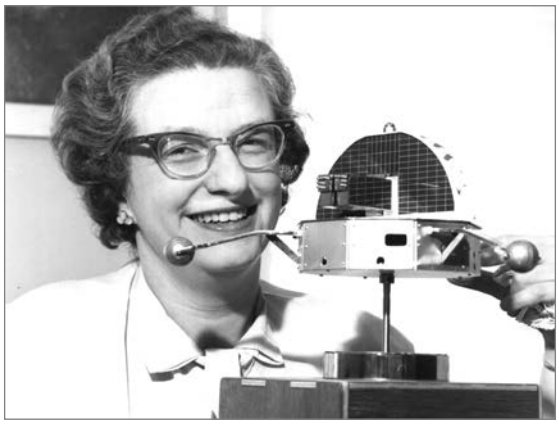
His dissertation "The Frontiers of Science Foundation: Transforming Math and Science Curricula in Oklahoma Secondary Schools, 1957–1964" deals with the work of a private group that pushed what we would now call STEM initiatives in Oklahoma after Sputnik. Our second Administrator, Jim Webb, came to NASA from work in Oklahoma, and he was deeply involved in the initiative that Rick was studying. So Rick spent quite a bit of time working with our NASA Headquarters archival team and doing research in our Historical Reference Collection. Rick very generously had a copy of his dissertation printed and bound, and he presented it to us for our Reference Collection.

Rick is not your typical grad student—he is the Executive Director of the Oklahoma Municipal Contractors Association and took up Ph.D. research in history at Oklahoma State University when most people would be thinking of retirement. (Also of note, his brother Bill is a space historian and video producer who has done a lot of work on the impact of Oklahomans who have been involved in the space program. Spoiler alert: there are lots of them.)

Did you witness history on 20 July 1969? Do you have memories of the Apollo era? Send in your memories of Apollo, and we'll select a few to highlight in our second-quarter newsletter in honor of the 50th anniversary of humanity's first footsteps on another world. E-mail *andres.almeida@nasa.gov* or tweet @NASAHistory with the hashtag #MemoriesOfApollo.

REMEMBERING DR. NANCY GRACE ROMAN

By Andres Almeida



Nancy Grace Roman displays a model of Orbiting Solar Observatory–1 in 1962. (Image credit: NASA)

As a child, Nancy Grace Roman loved looking at the stars. It was this love of stargazing that led her to a remarkable NASA career that spanned 20 years. Remembered by many as the "Mother of Hubble," Roman died on 25 December 2018 at the age of 93.

Growing up under the clear skies of Reno, Nevada, Roman enjoyed many nights of gazing at the constellations. In interviews, she has credited her mother with instilling a curiosity about the cosmos, especially when they would go on walks together and her mother would teach her about the constellations and the aurora borealis (when they lived in northern Michigan).

Despite little support from guidance counselors and teachers, Roman graduated from high school and earned her bachelor's degree in astronomy from Swarthmore College in 1946 and her Ph.D. in the same field from the University of Chicago in 1949. She did research at Yerkes Observatory and McDonald Observatory in Texas.

After a brief stint working as a radio astronomer at the United States Naval Observatory, Roman joined NASA in April 1959. The Agency was just six months old, but her expertise led her to become the first Chief of Astronomy in the Office of Space Science. There, she advocated for a large space-based observatory that ultimately brought forth the Hubble Space Telescope, the most significant advancement in astronomy since Galileo first used his own telescope 400 years earlier. The concept of an orbiting observatory was originally proposed by astronomer Lyman Spitzer in 1946, but it was Roman who propelled the idea to orbit. Her rounding up of scientists and program managers was instrumental in convincing Congress to fund such a large-scale project.

She was also involved in launching three orbiting solar observatories (you can find a scale model of one in our NASA Headquarters reference library) and three small satellites that used ultraviolet and x-ray technology.

> **"REMEMBERED BY MANY AS THE "MOTHER OF HUBBLE," ROMAN DIED ON 25 DECEMBER 2018 AT THE AGE OF 93."**

Long after she retired from NASA, Roman continued passing on her love of science and discovery to young people, particularly encouraging young girls to pursue careers in science, technology, engineering, and mathematics. Roman's likeness was used in a Women of NASA LEGO set alongside those of Margaret Hamilton, Sally Ride, and Mae Jemison.

For more on Dr. Roman's life and career, read her oral history conducted by Johnson Space Center historians at *https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/oral_histories/NASA_HQ/Herstory/RomanNG/romanng.htm*.

UPCOMING MEETINGS

National History Day 2019 will be held **9–13 June 2019** in College Park, Maryland. Visit *https://www.nhd.org/national-contest* for details.

The Experimental Aircraft Association (EAA) AirVenture will be held **22–28 July 2019** in Oshkosh, Wisconsin. Visit *https://www.eaa.org/en/airventure* for details.

The 2019 Joint Annual Meeting of the Council of State Archivists and the Society of American Archivists will be held **31 July–6 August 2019** in Austin, Texas. Visit *https://www2.archivists.org/conference* for details.

The annual meeting of the Society for Social Studies of Science (4S) will be held **4–7 September 2019** in New Orleans, Louisiana. Visit *http://www.4sonline.org/meeting* for details.

The 70th International Astronautical Congress will be held **21–25 October 2019** in Washington, DC. Visit *https://www.iac2019.org* for details.

RECENT PUBLICATIONS

Compiled by Chris Gamble

Dynamic Mars: Recent and Current Landscape Evolution of the Red Planet, edited by Richard J. Soare, Susan J. Conway, and Stephen M. Clifford (Elsevier, August 2018). This book presents observations, interpretations, and explanations of geological change at the surface or near-surface of Mars.

Mysteries of Mars, by Fabio Vittorio De Blasio (Springer-Praxis, August 2018). This book introduces the reader to the wonders of Mars, covering aspects of Mars ranging from our past perceptions of the planet through the latest knowledge on its history; its surface processes, such as impact cratering, volcano formation, and glaciation; and its atmosphere and climate.

The Strategic Defense Initiative: Ronald Reagan, NATO Europe, and the Nuclear and Space Talks, 1981–1988, by Ralph L. Dietl (Lexington Books, August 2018). This is a book about President Ronald Reagan's administration's strategy to end the Cold War.

Dust in the Atmosphere of Mars and Its Impact on Human Exploration, edited by Joel S. Levine, Daniel Winterhalter, and Russell L. Kerschmann (Cambridge Scholars Publishing, September 2018). In this book, 16 Mars scientists, mission engineers, planners, and medical researchers have reviewed our current understanding and identified the knowledge gaps in Mars's atmospheric dust.

Pioneers of Spaceflight, by Michael A. O'Neill (Danann Publishing, September 2018). Full of insights and accounts of the long journey to getting a human on the Moon, this book includes dozens of photographs and images relating to the space race and the Apollo 11 Moon landing.

Space Stations: The Art, Science, and Reality of Working in Space, by Gary Kitmacher, Ron Miller, and Robert Pearlman (Smithsonian Books, October 2018). Space stations represent both the summit of space technology and, possibly, the future of humanity beyond Earth. This book discusses past, present, and future space stations, both real ones and those dreamed up in popular culture.

The Smithsonian History of Space Exploration: From the Ancient World to the Extraterrestrial Future, by Roger D. Launius (Smithsonian Books, October 2018). This book is a history of international space

exploration paired with photographs, illustrations, graphics, and sidebars on key scientific and technological developments, influential figures, and pioneering spacecraft. The book examines space exploration's origins in the pioneering work undertaken by the ancients of Greece, Rome, and China, and it moves through the great discoveries of Renaissance thinkers including Copernicus, Galileo, and Kepler.

Space Atlas, 2nd Edition: Mapping the Universe and Beyond, by James Trefil (National Geographic (October 2018). Starting with the Sun and moving outward into space, science writer and physicist James Trefil describes each planet, some important moons, significant asteroids, and other objects in our solar system. Looking beyond, he explains what we know about the Milky Way and other galaxies and how we know it, with explanations of the basics of astrophysics, including dark matter and gravitational waves.

Infinite Wonder: An Astronaut's Photographs from a Year in Space, by Scott Kelly (Knopf, October 2018). Scott Kelly presents snapshots of life and work on the International Space Station, from spacewalks to selfies. Through his photographs he presents an argument for the preservation of our planet in the face of climate change.

Defying Limits: Lessons About Life from the Edge of the Universe, by Dr. Dave Williams (Simon & Schuster; Canadian Origin edition, October 2018). This is a memoir by Dr. Dave Williams, one of Canada's most accomplished astronauts.

The Race to the Moon Chronicled in Stamps, Postcards, and Postmarks, by Umberto Cavallaro (Springer-Praxis, October 2018). Through images of postage stamps, postcards, and letters in circulation during the Space Race, this book shows how the United States and the USSR employed different core tactics in the race to the Moon.

The Bomb and America's Missile Age, by Christopher Gainor (Johns Hopkins University Press, October 2018). In this book, the author explores the U.S. Air Force's March 1954 decision to build the Atlas, America's first intercontinental ballistic missile. Beginning with the story of the guided missiles that were created before and during World War II, the author describes how the early Soviet and American rocket programs evolved over the course of the following decade.

Disasters in Space: Stories from the US–Soviet Space Race and Beyond, by Hermann Woydt (Schiffer, October 2018). This book records more than a dozen American and Soviet space disasters from 1967 to the present day. Presented are tragic and near-tragic missions such as NASA's Gemini 6A and 8, Apollo 1 and 13, and Challenger and Columbia Space Shuttle disasters, as well as the Soviets' Soyuz 1, 11, and 18-1, along with others.

The Space Book Revised and Updated: From the Beginning to the End of Time, 250 Milestones in the History of Space & Astronomy, by Jim Bell (Sterling, revised edition, October 2018). Since the original edition of 2013, much has happened in the world of space exploration. This revised and updated edition includes the most exciting and newsworthy breakthroughs, from the groundbreaking discovery of the Trappist-1 system to the technologies of the future.

The Astronaut Selection Test Book: Do You Have What It Takes? by Tim Peake and the European Space Agency (ESA) (Century, October 2018). Part puzzle book, part guide, this book invites readers of all ages to learn about the European Space Agency's rigorous astronaut selection and training program. The book includes 100 real astronaut tests and training exercises for readers to try at home, outlining the full ESA selection process.

The Moon: From Inner Worlds to Outer Space, by Marie Laurberg, Anja C. Andersen, Stephen Petersen, and Ed C. Krupp (Louisiana Museum of Modern Art [Denmark], October 2018). The Moon has long furnished humankind with an artistic icon, an image of longing and object of scientific inquiry. Encompassing art, film, literature, architecture, design, natural history, and historical objects, and published on the 50th

anniversary of the first human landing (20 July 1969), the book surveys the iconography of the Moon, from Romantic landscape paintings to Space Age art.

Should We Colonize Other Planets?, by Adam Morton (Polity, October 2018). The author examines extraterrestrial colonization plans with a critical eye. He makes a case for colonization—just not by human beings.

Planetary Echoes: Exploring the Implications of Human Settlement in Outer Space, by Lukas Feireiss, Michael Najjar, et al. (Spector Books, October 2018). In this book, a broad, interdisciplinary list of contributors (scientists, astronauts, designers, philanthropists, inventors, artists, and curators) weighs in on the imaginable possibilities of space settlement.

Moon: The Art, Science and Culture of the Moon, by Alexandra Loske and Robert Massey (Ilex Press, October 2018). This visual history of the Moon explores humanity's endless fascination with its closest cosmic neighbor.

Outpost in Orbit: A Pictorial & Verbal History of the International Space Station, by David J. Shayler and Robert Godwin and edited by Dr. Gary Kitmacher (Apogee Books, October 2018). In 2018, we celebrated the 20th anniversary of the extraordinary orbiting laboratory, the International Space Station (ISS). The ISS represents what can happen when people from different backgrounds and different cultures come together with parallel dreams and aspirations. This truly astonishing feat of human ingenuity would not exist without the contributions and insights of people from almost every walk of life going all the way back to Isaac Newton. In this anniversary tribute, the reader is taken through a pictorial history of the Space Station.

Apollo to the Moon: A History in 50 Objects, by Teasel E. Muir-Harmony (National Geographic, October 2018). A celebration of the 50th anniversary of NASA's Apollo missions to the Moon, this narrative uses 50 key artifacts from the Smithsonian archives to tell the story of the groundbreaking space exploration program.

Mission Moon 3-D: A New Perspective on the Space Race, by David Eicher (Massachusetts Institute of Technology (MIT) Press, October 2018). July 2019 marks the 50th anniversary of Apollo 11's epochal lunar landing, when Neil Armstrong and Buzz Aldrin walked on the surface of the Moon. This book tells the story of the lunar landing and the events that led up to it with text and 3D images. A 3D viewer designed by astrophysicist (and lead guitarist with the rock group Queen) Brian May is included with the book.

Mercury: The View After MESSENGER, edited by Sean C. Solomon, Larry R. Nittler, and Brian J. Anderson (Cambridge University Press, November 2018). Observations from the first spacecraft to orbit the planet Mercury have transformed our understanding of the origin and evolution of rocky planets. This volume lays out the formation and large-scale evolution of the planet and the current plans and capabilities needed to explore Mercury further in the future.

NASA Langley Research Center: The First Century, by Amy Waters Yarsinske (America Through Time, November 2018). Langley research established many of the basic building blocks of aeronautics, changed the shape of aircraft, and paved the way for jet aircraft that could fly at supersonic speed. Whether it is testing airbags for space capsule landings, developing technologies to allow aircraft to fly at supersonic and hypersonic speeds, or studying Earth's atmosphere, Langley remains on the leading edge as it has since 1917.

The NASA Archives: 60 Years in Space, by Piers Bizony (Taschen, November 2018). Researched with the collaboration of NASA, this collection gathers more than 400 historic photographs and rare concept renderings, scanned and remastered using the latest technology and reproduced in extra-large size.

Ronald Reagan and the Space Frontier, by John M. Logsdon (Palgrave Macmillan, November 2018). Drawing from a trove of declassified primary source materials and oral history interviews, the author provides an account of President Ronald Reagan's civilian

and commercial space policies during his eight years in the White House.

The Cradle of American Space Exploration, by Kenny Mitchell (CGP Publishing, December 2018). The author, a retired NASA engineer and consultant, began his career in Huntsville, Alabama, in 1959 as a co-op student at the Army Ballistic Missile Agency located at Redstone Arsenal. He later managed many NASA projects, including the first NASA office in Moscow, Russia. Mitchell documented his life during the Apollo era and researched the many contributions of the men and women of NASA's Marshall Space Flight Center.

Mercury (Kosmos), by William Sheehan (Reaktion Books, December 2018). In this illustrated account, the author describes the growth of our knowledge of planet Mercury.

Planetary Defense: Global Collaboration for Saving Earth from Asteroids and Comets, edited by Nikola Schmidt (Springer, December 2018). Planetary defense cannot be achieved with technology alone; the chapters in this volume highlight the issues that arise when space science and technology intersect with political science. This complex interdisciplinary project not only demands global participation and collaboration, but also proposes the way we can achieve it.

Gemini 4: An Astronaut Steps into the Void, by David J. Shayler (Springer-Praxis, January 2019). The flight of Gemini IV in June 1965 was conducted barely four years after the first Americans flew in space. It was a bold step by NASA to accomplish the first American spacewalk and to extend the U.S. flight-duration record to four days. Despite the risks, the gamble that astronauts Jim McDivitt and Ed White undertook paid off. Gemini 4 gave NASA the confidence to attempt an even longer flight the next time. That next mission would simulate the planned eight-day duration of an Apollo lunar voyage.

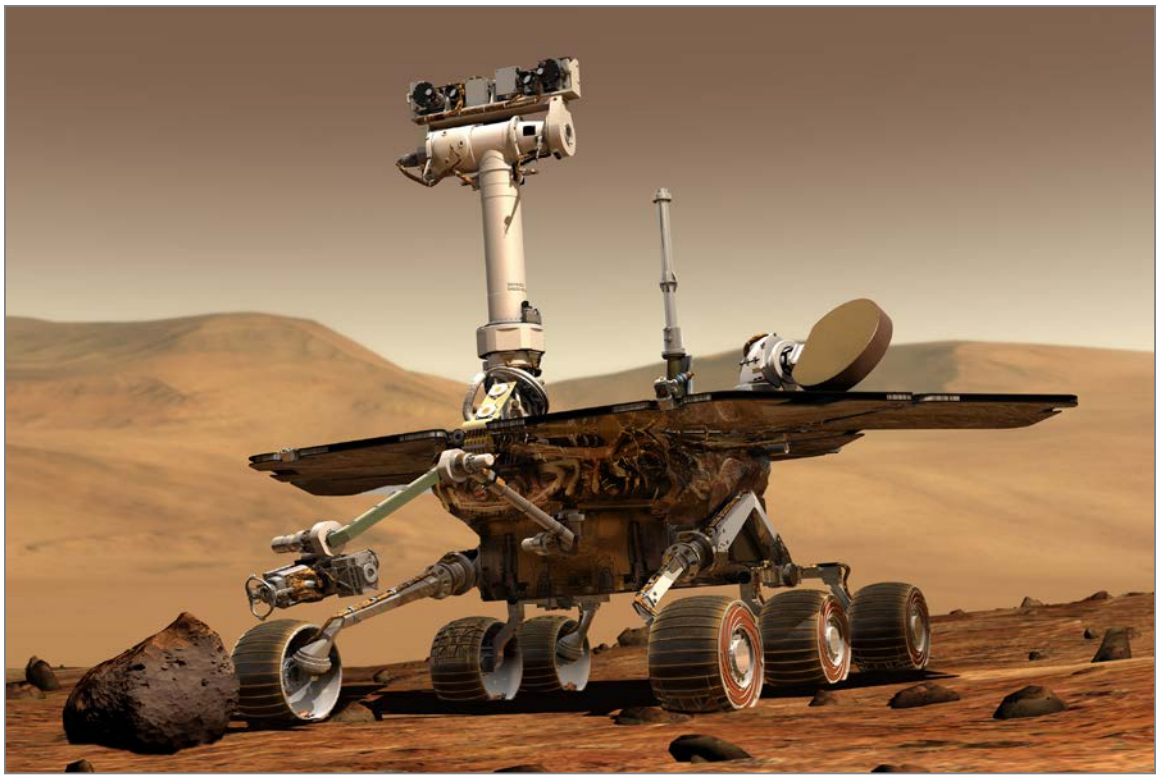
Saturn in the 21st Century, edited by Kevin H. Baines, F. Michael Flasar, Norbert Krupp, and Tom Stallard (Cambridge University Press, January 2019). The Cassini Orbiter mission, launched in 1997, has provided state-of-the-art information into the origins and workings of Saturn. Drawing from new discoveries and scientific insight from the mission, this book provides a detailed overview of the planet as revealed by Cassini. Chapters by eminent planetary scientists and researchers from across the world comprehensively review the current state of knowledge regarding Saturn's formation, interior, atmosphere, ionosphere, thermosphere, and magnetosphere.

Apollo on the Moon in Perspective, by Dr. Ronald A. Wells (CG Publishing, January 2019). The Apollo lunar surface photos are a national treasure—scenes that should be seen by everyone through the eyes of the photographers. Fortunately, with the aid of modern computer software, many of the photos can be so viewed in 3D. This book includes over 150 pages of 3D anaglyphs created painstakingly by the author. Included is a DVD-ROM that contains more than 950 3D images from the Apollo lunar photography and a pair of anaglyphic cyan/red viewing glasses.

Robots in Space: A NASA Insider Chronicles Unmanned Missions to the Planets, by Rod Pyle (Prometheus Books, January 2019). This perspective examines incredible missions of robotic spacecraft to every corner of our solar system and beyond. Some were flown into glory, while others were planned and relegated to dusty filing cabinets. The author profiles both the remarkable spacecraft and the amazing scientists and engineers who made them possible.

Spacewear: Weightlessness and the Final Frontier of Fashion, by Barbara Brownie (Bloomsbury Visual Arts, January 2019). This book explores how space travel has stylistically and technologically framed fashion and textile design on Earth and argues that technical garments for outer space appear to be becoming increasingly fashion-focused.

Early Exploration of the Moon: From Ranger to Apollo and Luna to Lunniy Korabl, by Thomas Lund (Springer-Praxis, January 2019). A total of 36 successful lunar exploration missions were conducted



This artist's concept shows the Opportunity rover on the surface of Mars. (Image credit: NASA/JPL/Cornell University, Maas Digital, LLC)

from 1959 to the last Apollo mission in 1972 and the final travels of the Lunokhod lunar rover in 1973. The spacecraft that enabled lunar exploration were ingenious and reflected the best efforts of talented people working with the technology of the day. This book showcases the engineering involved in those incredible machines.

War in Space—The Science and Technology Behind Our Next Theater of Conflict, by Linda Dawson (Springer-Praxis, February 2019). This book takes a look at how countries around the world might respond to full-scale satellite communications blackout.

Come Fly with Us: NASA's Payload Specialist Program, by Melvin Croft and John Youskauskas (University of Nebraska Press, February 2019). The book is the story of an elite group of space travelers who flew as members of many Space Shuttle crews but were not part of the regular NASA astronaut corps. These professionals, known as "payload specialists," came from a wide variety of backgrounds and were chosen for an equally wide variety of scientific, political, and national security reasons. The authors focus on this special fraternity of spacefarers and their individual reflections on living and working in space. Relatively unknown to the public and often flying only single missions, these payload specialists give the reader an unusual perspective on the experience of human spaceflight.

Houston, Space City USA, by Ray Viator (Texas A&M University Press, February 2019). *Houston, Space City USA* is a visual representation of Houston's historic ties to the U.S. human spaceflight program.

Honeysuckle Creek: The Story of Tom Reid, a Little Dish and Neil Armstrong's First Step, by Andrew Tink (University of New South Wales Press [Australia], February 2019). This book discusses the pivotal role that the tracking station at Honeysuckle Creek, near Canberra, Australia, played in the first Moon landing.

AIR FORCE FLIGHT TEST MUSEUM HIGHLIGHTS JOINT NASA–U.S. AIR FORCE LEGACY AT EDWARDS

By Peter W. Merlin, Air Force Flight Test Museum Volunteer

The X-4 Bantam (seen on the right) is part of the indoor collection of aircraft at the Air Force Flight Test Center Museum. (Image credit: USAF/Rebecca Amber)

The mission of the Air Force Flight Test Museum is to preserve the history and legacy of all flight research and testing conducted at Edwards Air Force Base (AFB) in California. That work includes programs undertaken by NASA, a major tenant on base since the 1940s, according to museum director George Welsh.

Through a long-standing alliance, the U.S. Air Force and NASA share the airfield at Edwards along with nearby restricted-use airspace, tracking facilities, and special range instrumentation. Many research projects have been joint efforts between the service and the civilian agency, beginning in the late 1940s with the Bell X-1, the first supersonic research airplane. Since then, the Air Force has provided test pilots, chase aircraft, and mission support for numerous revolutionary programs, including high-speed flight research with the XB-70 and YF-12, approach and landing tests of the wingless lifting bodies, advanced fighter technology integration (AFTI) using the F-16 and F-111, and the development of winglets and digital fly-by-wire controls. Similarly, NASA has often provided support for major Air Force Test Center projects and for smaller ones undertaken by Air Force Test Pilot School classes at Edwards.

"We are telling that story," said Welsh, "through artifacts that NASA is loaning to us for display."

Since its inception, the museum has striven to acquire a variety of NASA aircraft that were flown at Edwards, as well as other significant artifacts. Some notable examples include the highly modified NF-111A used for the AFTI and Mission Adaptive Wing projects, a B-57B that measured high-altitude turbulence, a preproduction F-15A used for propulsion and controls research, an F-104G chase plane, and the unpiloted X-36 and X-48 subscale research aircraft. Several recent additions to the museum collection represent various aspects of the Space Shuttle Program, which concluded in 2011 following three decades of orbital missions. These include a modified Gulfstream G-II/III Shuttle Training Aircraft used by astronauts to practice

low-lift-to-drag landing and a Crew Transport Vehicle for transferring astronauts from Shuttle orbiters to NASA medical facilities after space missions. A modified bomber known as the NB-52B, used as a launch platform for numerous piloted and unpiloted research craft from the X-15 in 1959 to the X-43 in 2004, is currently displayed next to the Edwards AFB North Gate.

Welsh and his staff were particularly pleased with the addition of two unique vehicles to the museum's exhibit hall, the M2-F1 lifting body and the sole surviving Lunar Landing Research Vehicle (LLRV). Both vehicles have colorful nicknames and histories.

"TO COMPLEMENT THE M2-F1 FOLLOWING ITS ARRIVAL IN JANUARY 2015, MUSEUM STAFF AND VOLUNTEERS DEDICATED A SECTION OF THE EXHIBIT AREA TO HIGHLIGHT NASA'S ACCOMPLISHMENTS AT EDWARDS. 'WE HOPE TO BUILD ON NASA'S STORY IN THE MUSEUM AND ACQUIRE MORE ARTIFACTS ON LOAN,' SAID MOORE."

Nicknamed the "flying bathtub," the M2-F1 was the first full-scale, piloted lifting body. NASA research pilots and Air Force test pilots used it to demonstrate the low-speed handling qualities of a wingless reentry vehicle. The lightweight craft was unpowered but made hundreds of glide flights that began and ended on Rogers Dry Lake at Edwards. Early tests employed a Pontiac convertible to tow the vehicle aloft; later, a DC-3 was used for higher-altitude flights. These tests paved the way for a series of rocket-powered heavyweight lifting bodies that were launched from NASA's Boeing NB-52B Stratofortress mother ship during the 1960s and 1970s.

"The M2-F1 had a handmade wood and fabric shell wrapped around a tubular steel frame," said museum curator Tony Moore. "You can see the craftsmanship when you look inside the cockpit," he added. "It's truly a work of art."

To complement the M2-F1 following its arrival in January 2015, museum staff and volunteers dedicated a section of the exhibit area to highlight NASA's accomplishments at Edwards. "We hope to build on NASA's story in the museum and acquire more artifacts on loan," said Moore.

NASA's Armstrong Flight Research Center loaned LLRV number 2 to the museum in 2016. It was the second of two such vehicles tested at Edwards AFB in the early 1960s before being sent to NASA's Manned Spacecraft Center (now Johnson Space Center) in Houston, Texas. Constructed in the form of a square framework of tubes and machinery wrapped around a vertically oriented turbojet engine, with four legs terminating in caster-mounted wheels, it was quickly dubbed the "flying bedstead."

The two LLRV craft mimicked the flight characteristics of a vehicle operating in the airless, low-gravity lunar environment and served as prototypes for three additional and slightly larger Lunar Landing Training Vehicles (LLTVs). Astronauts flew both types to hone their piloting techniques in preparation for landing on the Moon during the Apollo lunar exploration program. It was hazardous work—LLRV-1 and two LLTVs were lost in nonfatal mishaps—but absolutely vital. Neil Armstrong, the first human to step onto the Moon's surface, said the Apollo missions would not have succeeded without the high-fidelity simulation provided by the LLRV and LLTV.

Welsh said that his ultimate goal is to display NASA items along with all the other historic Edwards aircraft and artifacts at the future Flight Test Museum (and Education Center) that is currently under

construction just outside the Edwards West Gate so that they will be accessible to the public. Currently, only those persons with access to the base, or part of escorted tour groups, may visit the existing location. "We want to make the museum more accessible to everyone," he said.

Welsh added, "Our unique collection of artifacts allows us the opportunity to educate the public on the long history of cooperation between NASA and the Air Force on some of the many joint research programs that have taken place at Edwards."

For more on the Air Force Flight Test Museum and how to schedule a tour through Edwards AFB, visit *http://www.afftcmuseum.org/*.

"OUR UNIQUE COLLECTION OF ARTIFACTS ALLOWS US THE OPPORTUNITY TO EDUCATE THE PUBLIC ON THE LONG HISTORY OF COOPERATION BETWEEN NASA AND THE AIR FORCE ON SOME OF THE MANY JOINT RESEARCH PROGRAMS THAT HAVE TAKEN PLACE AT EDWARDS."

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MOMENT IN NASA HISTORY

During a nighttime training session, a multiple exposure captures the movement of the Lunar Excursion Module Simulator (LEMS) at the Lunar Landing Research Facility at NASA's Langley Research Center. The LEMS was a piloted vehicle used to familiarize the Apollo astronauts with the handling characteristics of lunar-landing-type spacecraft. (Image credit: NASA)

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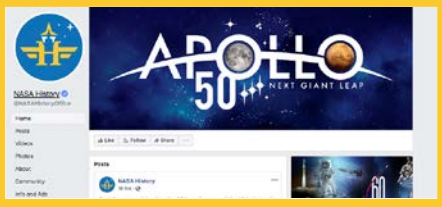

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