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JPL

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Featured Stories

How the Deep Space Network Supports Artemis I

By Laurance Fauconnet

Over 50 years ago, NASA captured the world's imagination and inspired generations with the Apollo 11 Moon landing. Back then, NASA's communications networks were crucial to mission success. These days, NASA's Deep Space Network (DSN), which is managed and operated by JPL, provides a critical service as the Artemis I mission moves us forward to the Moon.

The DSN–part of JPL's Interplanetary Network Directorate–handles communications for Artemis I beyond low-Earth orbit. This includes the mission's outbound trajectory corrections, outbound powered flyby, return powered flyby burns, and return trajectory corrections. NASA's Near Space Network, which is managed and operated by the Goddard Space Flight Center in Greenbelt, Maryland, provides communications data in and below low-Earth orbit.

At the Moon, the DSN will enable insertion into distant retrograde orbit. Distant retrograde orbit is a highly stable orbit in which the Orion spacecraft travels retrograde, or opposite, from the direction the Moon travels around Earth. The Deep Space Network will maintain communications with Orion over five stages:

in distant retrograde orbit; during the burns for departure; return power fly-by; return transit; and the final return trajectory correction burn, with a hand-off to the Near Space Network's TDRS constellation.

The DSN will help facilitate communications for all three of the Artemis I mission's secondary payload deployment stops. The 10 CubeSats launching with Artemis I are small satellites that will be deployed along Orion's trajectory to provide additional research opportunities for scientists and engineers. After deployment, most of the CubeSats will communicate through the Deep Space Network and pick up tracking data used for their navigation.

"The communications requirements the DSN is meeting for Artemis I highlight the breadth of capabilities of the system, and the importance of continued investments and improvements to our facilities such as the ongoing construction of the newest 34-meter antenna at Goldstone," said Interplanetary Network Director Suzy Dodd.

A Legacy of Supporting Lunar Exploration

JPL has a rich history of lunar exploration. In the 1960s, JPL began to develop robotic spacecraft to explore other worlds. This effort began with the Ranger and Surveyor missions to the Moon, paving the way for NASA's Apollo astronaut lunar landings. Rangers 7, 8, and 9, launched in 1964 and 1965, taking photos of the Moon as they descended toward intentional impacts. From 1966 through 1968, Surveyors 1, 3, 5, 6 and 7 made soft landings on the Moon.

That legacy of human lunar exploration also includes the Deep Space Network.

Although primarily tasked with tracking uncrewed spacecraft exploring beyond the geosynchronous orbit, the Deep Space Network has a long history in supporting crewed lunar missions.

On July 20, 1969, NASA astronauts Neil Armstrong and Buzz Aldrin, with Michael Collins orbiting above, became the first humans to land on another world, our Moon. Affixed to the inside of the Eagle lander's door was a small, unconventional TV camera. The extraordinary images it captured showed Armstrong and Aldrin amid what they described as the "magnificent desolation" of the lunar surface.

Getting this incredible video to hundreds of millions of people back on Earth, gathered around countless television sets in rural homes, on city streets, and in remote villages around the globe, was up to the flexibility and resourcefulness of NASA's Manned Space Flight Network and the Deep Space Network.

The Deep Space Network designed the Manned Space Flight Network, a set of tracking stations built to support the Mercury, Gemini, Apollo, and Skylab space programs. The Manned Space Flight Network sites were constructed near the Deep Space Network complexes, located in Goldstone, California; Madrid, Spain; and Canberra, Australia so that the Deep Space Network could provide additional support. After Apollo, the Manned Space Flight Network no longer needed the large antennas that had been used for lunar communication, and they were eventually transitioned to the Deep Space Network.

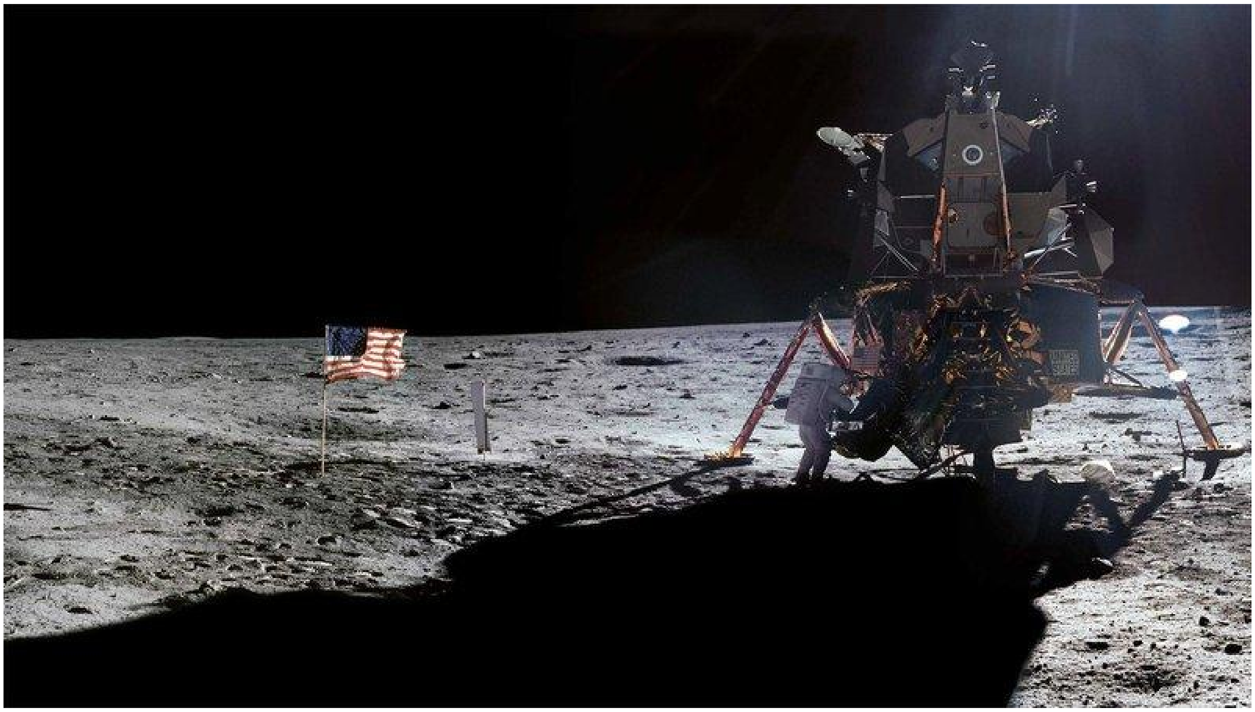
During lunar landing and liftoff, NASA "dishes" in Madrid, Spain, would provide tracking support for Apollo 11. But, at the time of the Moonwalk, Madrid was facing away from the Moon and couldn't "see" it. The job of getting those first historic pictures down to the world fell to tracking stations in Australia and here in the United States.

When Armstrong finally started descending the Lunar Module ladder three hours after the Eagle landed at Tranquility Base, a 64-meter antenna at the Deep Space Network complex in Goldstone, California received the first downlink, and two-way communication from the surface of the Moon.

However, by the time Armstrong reached the foot of the ladder, Mission Control in Houston, Texas switched the transmission to NASA's Honeysuckle Creek's 26-meter antenna located outside of Canberra, Australia. The improvement in picture quality was extraordinary.

But, responsibility for voice communications remained at Goldstone.

Those iconic words in history—"That's one small step for (a) man, one giant leap for mankind,"—ended their 240,000-mile journey to Earth at one location, while the pictures of Neil Armstrong speaking them came to be seen through another.



Apollo 11 Commander Neil Armstrong working at an equipment storage area on the lunar module. During Armstrong's first moonwalk, JPL's Deep Space Network complex in Goldstone was responsible for voice communications. Image Credit: NASA/JPL-Caltech

After almost nine minutes into the broadcast, a 64-meter dish at Parkes Observatory located in Parkes, New South Wales, Australia provided an even better picture. Television transmission would continue through July 23, 1969.

Since then, the 64-meter antenna at Goldstone has been expanded to 70 meters. It has accumulated a rich legacy during its many years of supporting space exploration. In addition to capturing the words of astronauts on the Apollo moon missions, the dish has communicated with every one of NASA's major robotic solar system explorers. The antenna enabled the world to see the first-ever close-up images of Jupiter, Saturn, Uranus and Neptune, their rings, and their myriad moons by the Pioneer, Voyager, Galileo, and Cassini missions. The antenna has also communicated with NASA's Mars missions.

NASA has pushed the boundaries of space travel, and the antennas of the Deep Space Network are the indispensable link to explorers venturing beyond Earth. As we continue to explore the Moon and beyond, the Deep Space Network is there to provide the crucial connection for commanding our spacecraft and receiving never before seen images and scientific information, propelling our understanding of the universe, our solar system and ultimately, our place within it.

Fast Facts on the Deep Space Network

- Provides the Artemis I mission 24/7 support for 42 consecutive days.
- Supports a minimum of 24 maneuvers during the Artemis I mission.
- Performs nearly 1,600 hours of tracking for the Artemis I mission across all three DSN complexes around the world.
- Tracks a total of 9 CubeSats that are part of Artemis I's secondary payload.

- Takes on average about 1.3 seconds for a communications signal to reach the Moon from the surface of Earth.
- Is home to three complexes spaced equidistant from each other – Deep Space Network 120 degrees apart in longitude – around the world. These sites are at Goldstone, near Barstow, California; near Madrid, Spain; and near Canberra, Australia
- Includes fourteen operational antennas located across the three complexes.

Follow the Journey

- Follow the journey of Artemis I on NASA TV.
- See the DSN communicate with Artemis I in real time at DSN Now.
- Learn more about Artemis I.

You can take a 360 virtual tour of the massive 70-meter antenna from your computer or phone. Check out the 360 video tour here.

Download three eye-catching posters featuring the larger 70-meter (230-foot) antennas located at the three Deep Space Network complexes in the United States, Spain, and Australia. Download the posters here.

A Mars 2020 Rover Mechanical Team meeting in December 2016 using ProtoSpace to assess potential snag hazards during the separation of the Descent Stage's bridal cables.

High Bay in a Headset

By Celeste Hoang

When JPLer Scott Nowak packed his bags for a work trip to India last year, he made sure to bring a small but vital item in his suitcase: an augmented reality (AR) headset.

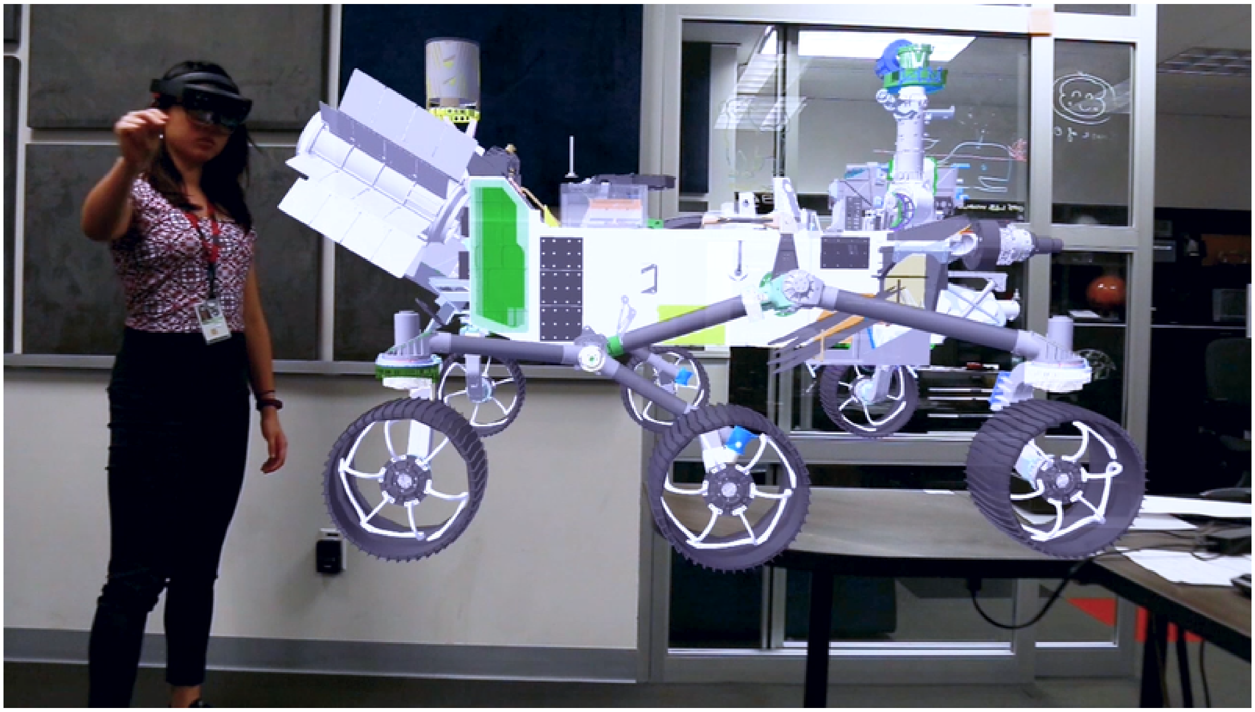
Nowak, a mechanical integration engineer for NISAR—the NASA-ISRO Synthetic Aperture Radar, an Earth-observing mission co-developed with the Indian Space Research Organization (ISRO)—was traveling to Bangalore to meet his international colleagues. He had one primary goal in mind: to impress upon the team the specific challenges of a payload of NISAR's size.

"NISAR has a 9-meter deployable boom and a 12-meter deployable antenna," Nowak explains. "No human is ever going to be able to see those deployed all together on Earth."

The virtual playground, however, is a whole lot bigger. Instead of explaining to the ISRO team with words what lay ahead, he showed them with the headset.

Nowak pulled up ProtoSpace, an augmented reality computer-aided design (CAD) model visualization tool developed at JPL and currently managed in ITSD's Division 174. Inside the AR headset, NISAR's massive payload had plenty of room to deploy. One by one, ISRO team members took turns projecting the spacecraft model into the space they were standing in—and voila, they could see exactly what Nowak wanted them to understand.

"It was great to communicate the scale of the work when our payload was in Pasadena, but the team we're talking with was in Bangalore," Nowak says.



A ProtoSpace user testing out the augmented reality visualization tool for a rover model.

The Pros Behind ProtoSpace

The use of augmented reality isn't new to the Lab, and some JPLers may already be familiar with the years-old HoloLens software OnSight developed in the Ops Lab that allows people to "walk on Mars."

But since ProtoSpace began in 2015, the platform has scaled up its technology and services to a point where missions can use it for a variety of purposes as a critical team tool, including the design, testing, and integration phase of their project. Last year, ProtoSpace was selected as JPL's entry for the 2021 NASA Software of the Year Award, receiving Honorable Mention in the competition.

The same year, Mixed Reality Developer Benjamin Nuernberger, Software Systems Engineer Sam Berndt, and UX Designer Rob Tapella took over as ProtoSpace co-leads.

"The main value ProtoSpace brings is that it helps people understand complex spatial relations and communicate together," says Nuernberger. "It lets you make more confident decisions, and by doing that, you can avoid risky situations or situations where you have to rework a potentially dangerous path."

For the uninitiated, getting ProtoSpace up and running is straightforward: users simply upload their CAD to the platform and the virtual playground is theirs.

Meant to be a collaborative software tool, ProtoSpace provides three core ways for teams to work together: users can work at real scale by walking through, presenting, and discussing complex models before building the hardware; they can blend the virtual with the physical by using the software to understand spatial relationships by overlaying ideas onto physical hardware; and teams can easily interact with models by using a collaborative toolbox to transform and explore CAD models without the need for a CAD expert.

In NISAR's case, Nowak has seen firsthand how instrumental the tool has been for both collaboration and the ease and safety of assembly, testing, and integration.

"Before a big lift, we put the headsets on and we can move something into place by projecting it and showing people what the working area will be like so we can understand if there will be any issues or close clearances," he says. "We've had some really close clearance lifts and we bide down risk by understanding the intricacies before we have two tons of hardware on a crane hook."

An added bonus: "[ProtoSpace] brings the 'wow' factor," Nowak says of showing off the software in India. "It was a great ice-breaker and people lit up and got excited about the future work."

That wow factor works both abroad and at home. On Lab, NISAR is the first project to use ProtoSpace in the high bay for the long term, and the software has been especially helpful and impressive when VIP guests—including the head of NASA and new JPL Director Laurie Leshin—pay a visit to scope out the work, according to Nowak.

Viewing a crucial integration operation on the CGI instrument planned for 2023.

Nuernberger, Berndt, and Tapella now champion the software across Lab, developing and tweaking new solutions and processes for the platform to meet projects' various needs, and moving through JPL's Enterprise 2.0 Enterprise Change Control Process (ECCP) to make ProtoSpace an institutional offering.

In the last couple of years, SWOT—the Surface Water and Ocean Topography mission—bought two new HoloLens headsets to take ProtoSpace to France so the engineers and scientists at French space agency collaborator Centre National d'Etudes Spatial (CNES) could take a virtual look at the incoming scientific payload that is now currently being [integrated with the rest of the satellite] near Cannes.

Beyond Earth, ProtoSpace is also being used by teams for Europa Clipper, the Roman Space Telescope Coronagraph Instrument (CGI), and Mars Sample Return.

For now, the ProtoSpace team is also focusing on new use cases, says Nuernberger. While the core process remains in uploading and viewing CAD models, sometimes projects approach the team with new challenges: visualizing a cable harness over a physical mockup of a structure; helping the Cold Atom Lab create 3D animations for their maintenance procedures that are used by astronauts; and, at the height of the pandemic, using ProtoSpace to build out 3D assembly instructions on the web for [JPL's mass-producible ventilator, VITAL].

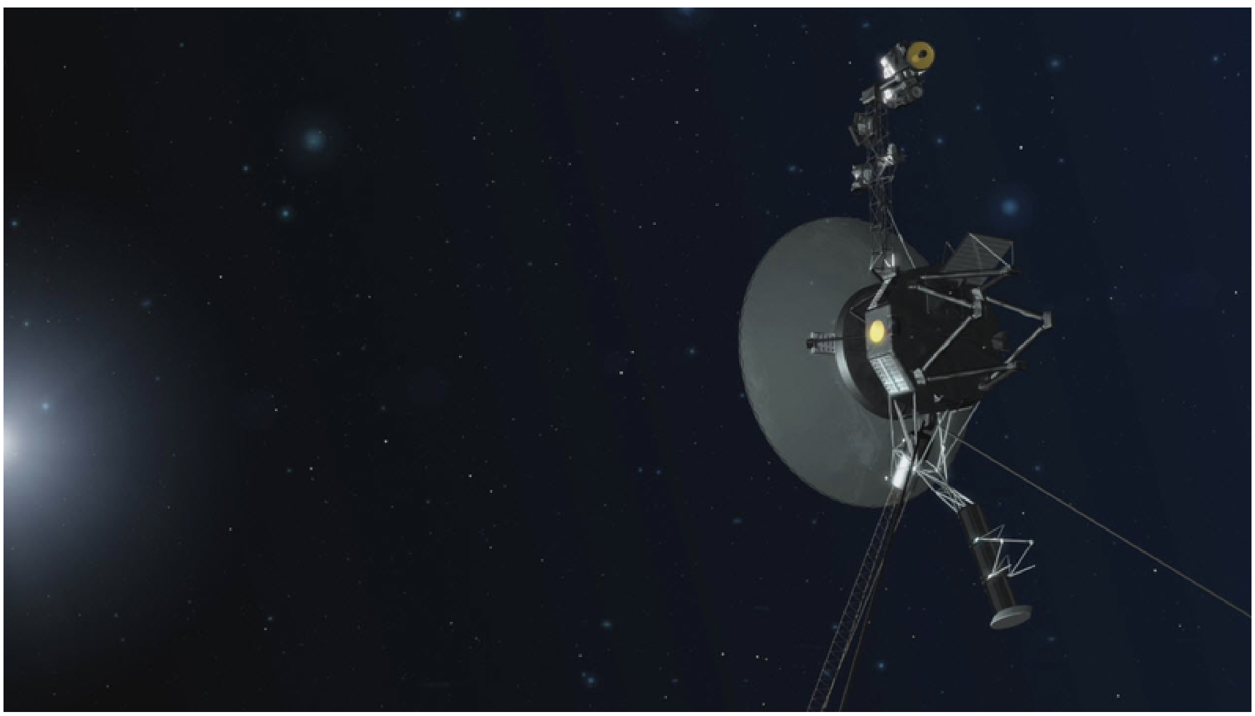
Whatever the use, Nuernberger, Berndt, and Tapella are proud to be part of the early stages of a technology they predict will be around for the long haul.

“I think augmented reality is really the future of how humans interact with the environment around them,” says Berndt, who first came across the Ops Lab and walked on Mars with a headset six years ago when he was still a JPL intern. “I believe that AR headsets are going to be commonplace within the next few years—as robust as an iPhone.”

For Nuernberger, the reward comes in putting in the daily work and seeing firsthand the value it brings.

“You can develop a project and never see your end user, but at JPL, you get direct access to the engineers working on amazing spacecraft and hardware,” he says. “To see them using this product and how it makes their job easier and more fun made me realize this is a great product and I want to keep working on it.”

End users may be the endgame, but there’s tangible value in this virtual tool for everyone involved.



On Voyager’s 45th, A Look Back and a Look Ahead

By Celeste Hoang

Sometimes, 45 years starts with a split-second decision.

The year was 1976, and Linda Spilker was a fresh-faced college graduate with a physics degree to her name and the Los Angeles Times in her hand. She—like many recent graduates of her time were likely doing—was scouring local newspapers for job listings. One post caught her eye in a heartbeat: there, in black-and-white, was an opening at JPL.

Spilker applied immediately, and after a successful round of interviews, was not only offered a job, but a choice: She could either work on Viking's extended mission, or join a new mission named Voyager.

"I said to them, 'Voyager? Hmm, I've never heard of that. Where is it going?'" Spilker recalls. "They said Jupiter and Saturn, and if it goes well, one of them will go on to Uranus and Neptune. And I remembered in third grade, I had my little telescope and used to look at the Moon and Saturn, and would write reports on them. Now here was a chance to visit four planets. How can you pass that up?"

She didn't. Spilker, now the mission's deputy project scientist, said yes to Voyager without knowing, of course, that the spacecraft would alter the trajectory of her career and life—and the lives of so many others who worked on or followed the mission—for more than four decades.

This month, the twin Voyager probes celebrate another milestone: 45 years as NASA's longest-operating mission and the only spacecraft to ever explore interstellar space. (See where the spacecraft is now with NASA's Solar System Interactive.) The probes are also popularly known for each carrying a Golden Record, a 12-inch gold-plated copper disk containing sounds and images selected to portray the diversity of life and culture on Earth.

At JPL, Voyager has become a multi-generational mission for the Lab community, touching the lives of veteran JPLers who worked on it from its beginnings in the 1970s, to the postdocs and graduate students who continue to study the spacecraft's new data to this day.

Says current Project Manager Suzy Dodd: "The Voyagers have continued to make amazing discoveries, inspiring a new generation of scientists and engineers. We don't know how long the mission will continue, but we can be sure that the spacecraft will provide even more scientific surprises as they travel further away from the Earth."

Long printout of stellar occultation of Saturn's rings observed from Voyager 2 in 1979.

Golden Memories

Spilker's career launched the same year as Voyager, when she started as the Infrared Interferometer Spectrometer and Radiometer (IRIS) assistant experiment representative in 1977. At the time, the newly-minted JPLer would put together sequences for the IRIS scientists, and see them uplinked to the spacecraft.

“I would watch as the data came back and say to myself, ‘That’s my observation,’” Spilker says.

Her work has since spanned decades at the Lab on a number of other missions—including project scientist of Cassini—and her return to Voyager as its deputy project scientist in 2021, under current Project Scientist Ed Stone, is a full-circle personal and professional moment. It’s also a role that lets her relish in commemorating the anniversary with her fellow colleagues.

“It’s an important milestone for a mission that’s lasted so long to celebrate scientific accomplishments and also the people,” says Spilker. “Think how many careers it has launched, and I'm certainly one of those, and there are many examples at JPL. This is a chance to enjoy making it to 45 years, and to look ahead.”

While many are looking to Voyager’s future, perhaps what’s most precious lies in the past. Decades later, Spilker can still recall textured memories of printing out Voyager’s stellar occultation data of Saturn’s rings on long rolls of paper and lining JPL’s hallways with them.

“I would walk up and down, looking at the data, and with my pencil mark and circle places that looked interesting,” she says. “And I’d say, ‘Hey, I’m walking through Saturn’s rings!’”

For a few other Voyager team members, their favorite memories of being part of the historic mission are arguably the real golden record.

> **Suzanne Dodd — Science Sequence Designer (1984-1985); Science Integration Engineer (1985-1989); Project Manager (2010-present):** I think from my first day on Voyager, the memory I will always have is of the Neptune encounter. As the Science Integration Engineer, I was responsible for the closest approach sequence for Neptune—all the images, and all the most challenging parts of the flyby. There were 11 instruments that all wanted to take data at the same time when they couldn’t, and Neptune is 30AU from Earth, so there’s much lower light levels. The engineering team had to develop different processes and algorithms to work around those obstacles. You work very hard to make the best sequence possible, and you send it to the spacecraft and cross your fingers and hope it works as anticipated. And it did. I was really proud of my work. I was really excited for the science that came down and there was a lot of energy at JPL. We don’t build spacecraft just to build spacecraft—we do it to get science data back. We had no idea what Neptune and Uranus looked like until Voyager started taking pictures of them. That’s the excitement—it’s the discovery.
>
> Voyager also taught me that when you work on a flight project and operations team, it’s about being part of a team. You’re all pulling for the same goal. It’s important to have that team mentality when you work in flight operations. You’re not a solo engineer—you’re part of a bigger cause, and you need to keep that in mind as you work through tough problems and bad days.
>
> Voyager has outlasted anyone’s wildest dreams from both a longevity and a discovery standpoint. It’s made more discoveries about planets, heliosphere, and interstellar space than anyone could have guessed. Because of where Voyager is in situ, no mission will get back there for 50 years or more. Each piece of data is unique and critical to forming our understanding of the local interstellar space and how our Sun and other stars interact. We need to continue to operate this spacecraft as long as we can to get those unique bits of data. I think we could certainly do that for another five years if all goes well, and fingers crossed, we could probably get it going for another 10 to 15 years. If we were able to get it to 2035, that would be 200AU. I would say the mission stretch goal is to be taking science data from 200AU.

Todd Barber — Voyager propulsion engineer (2017-present): I think my favorite memories on Voyager over the last five years were the moments when we switched to Trajectory Correction Maneuver (TCM) thrusters, a second backup option after experiencing thruster degradation on the other branches. Even though these TCM thrusters had not been used for over three decades, they fired right up and began controlling pitch and yaw on both Voyager 1 and 2. Despite the current challenges, especially on Voyager 1, I would never bet against the resiliency of these two beautiful machines. It is the honor of my career to fly the very mission that inspired me as a junior high school student in Kansas. I am most grateful that the Voyager team, many of whom have spent the bulk of their careers on the mission, have welcomed me so warmly to the team. They always were my heroes.

Bruce Waggoner — Voyager mission assurance manager and end of mission system engineer (1986-1990; 2015-present): The Neptune flyby will always be the highlight of my career. Nothing will ever come close. How often do you get to investigate a completely unexplored planet, its satellite system including Triton, a ring system, and a magnetosphere all in a matter of 12 hours or so? I don't have the words to express what that experience was like.

As Voyager celebrates another birthday, JPLers have another opportunity to reflect and pay homage to one of the Lab's greatest scientific and engineering achievements.

For Spilker, she rests assured knowing that the end—whenever it happens—is never really the end.

"People often want to know how long Voyager will last and yes, at some point we'll run out of power," she says. "But the Golden Records will be our silent ambassadors in interstellar space, waiting for whoever may find them and want to know what Earth was like."

JPL's Electronic Flight Parts Inventory Is Set to Soar With Big Upgrade

By Taylor Hill

On a warm and sunny first day of August, crowds gathered along the backside of Building 241—where trucks and forklifts are typically onloading and offloading spacecraft parts and assemblages—for something that stretch of road doesn't often see: cake, cookies, and live music from JPL's "Shop 300" band.

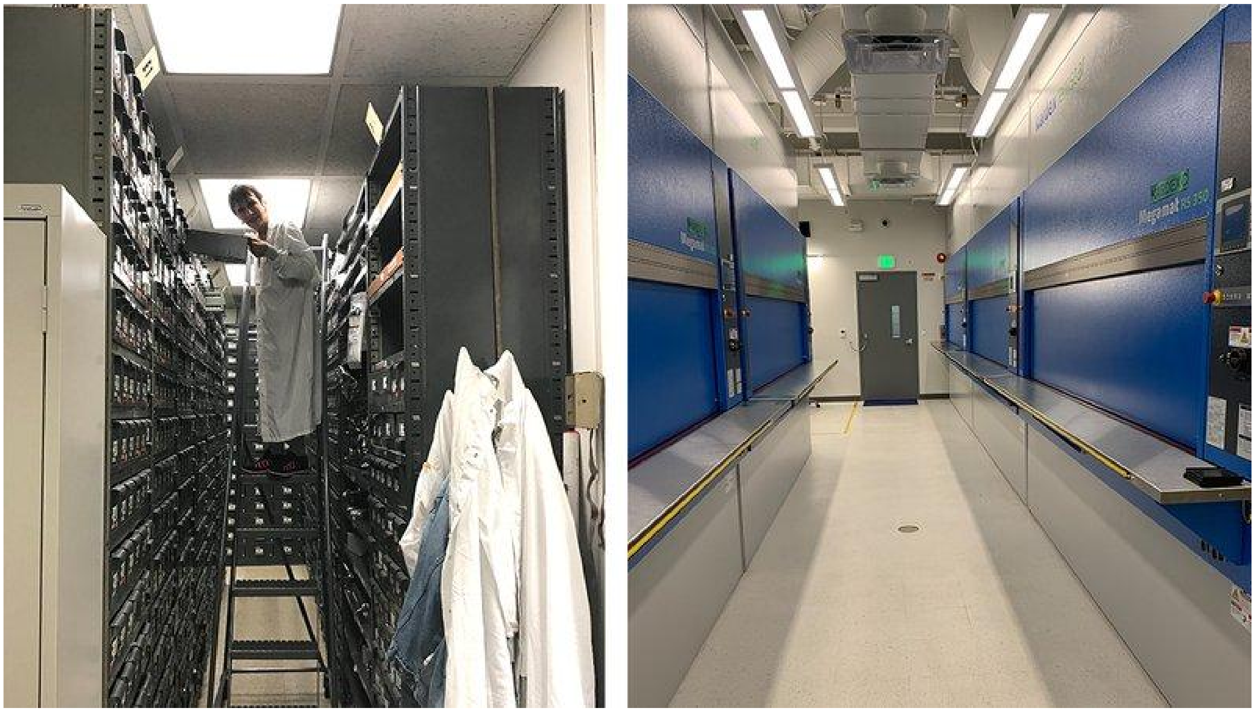
The celebration marked the grand reopening of JPL's flight store on Aug. 1, rebranded as the EEE Component Inventory area. JPLers can now head to B241-107 to pick up electrical, electronic, and electromagnetic (EEE) parts for use across nearly all project's electronic subsystems.

"I made a promise years ago to my bosses and fast forward to this day, and those promises have been kept," said Mohammad Mojarradi, Component Engineering and Assurance Office section manager. "We have been able to convert and modernize a major facility that we are the custodian of, and brought it into the 21st century to become one of the crown jewel facilities at JPL."

The renovation in Rooms 105 and 107 in Building 241 includes replacing old and outdated shelving and storage cabinets with automated carousel storage systems. Now the resistors, capacitors, transistors, microprocessors, microcircuits, memory components and more that are required to run JPL's spacecraft and robots are more safely and efficiently stored—and easier to access than ever before.

"The value of the parts we house is tremendous, and it was a long time coming to modernize the area," said Deputy Section Manager Jeremy Bonnell. "The previous binning system was antiquated, and we wanted better for our team."

The planning process started in 2018, and the team evaluated the facility from floor to ceiling, discovering an ironic safety problem: Hovering just above millions of dollars' worth of electronic flight components resided a fire sprinkler system, nearly blocked by the tall shelving, and set to inflict water damage on countless pieces of electronic parts if the system was ever triggered.



Left: the outdated storage shelving at the old "Flight Parts Store." Right: the upgraded Kardex Remstar Megamat carousels that allow for automated parts selection and retrieval.

The team found a solution, thanks to JPL's Occupational Safety Program Office (502), which cited a NASA requirement that all facilities housing essential hardware valued over $25 million must be protected by a gaseous fire suppression system—meaning inert gas and chemical agents should be the first line fire protection system, in addition to the water-based system to better protect the EEE parts.

After picking the automated vertical carousel machines best suited for the space, the team had a floor issue, too: new reinforced concrete had to be poured to withstand the weight of the multi-ton storage equipment. Funds for the renovation were approved in 2020, but the pandemic put its characteristic delays on the groundbreaking and construction. Over the course of the nearly two-year renovation, all inventory and kitting operations were relocated to Building 84.

In total, five machines—called Kardex Remstar Megamat carousels—are now in place in Building 241. The computerized storage system allows for 60 percent more storage capacity compared to standard shelving, and provides users with an easy, automated part selection and retrieval process.

“Let's say you've got 100 parts that you need to pull for your project that are in our inventory,” said Nancy Chiang, group supervisor of Parts Acquisition (5142). “We can input that list into the computer, and the computer will pull those parts from all five of our machines in sequence. So you'll grab all of the parts as they come out of the carousel of the first machine, move to the next one, and so on.”

It's a new level of efficiency for customers—with 46,000 EEE parts now available at the touch of a button—and a higher standard of safety for the Parts Acquisition group.

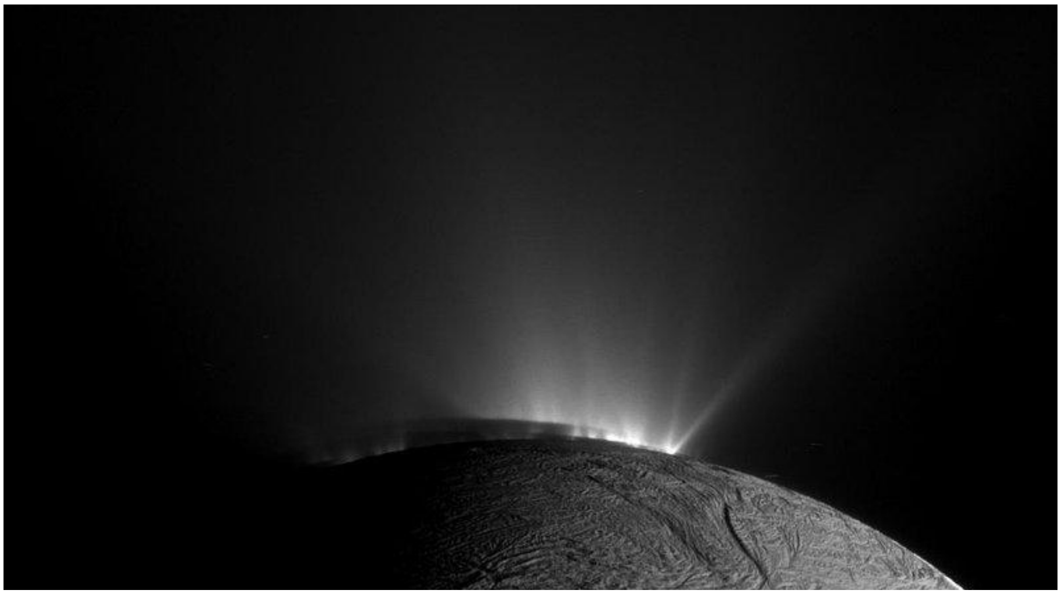
“Before, we were manually pulling these parts out of bins that went up to the ceiling, and we were using a step ladder to get to them,” Chiang said. “I feel better knowing our team is safer in this environment, and the parts are safer too, thanks to the upgraded fire system.”

Bonnell hopes the team now feels like they are working in a state-of-the-art facility they can be proud of.

“From a broader JPL and mission standpoint, you're going to see a facility that is now utilizing an efficient footprint with automated parts carousels, and a kitting area with specially designed electrostatic discharge work stations—specifically set up to handle these parts safely,” he said. “These two rooms in

Building 241, they're not big, but they supply parts to nearly all JPL flight projects and nearly all of the assemblies. It's an efficient, finite setting, and we've really focused on making the most out of every available square foot that we could."

Events



Von Karman Lecture: Ocean Worlds Life Surveyor

Thursday, Sept. 15
7 p.m. to 8:30 p.m.
Watch on YouTube

The Ocean Worlds Life Surveyor (OWLS) is the first life detection suite to explore a wide range of size scales, from single molecules to microscopic organisms, in a water sample. OWLS is an integrated, portable, and autonomous life-detection instrument suite designed to identify and characterize life on ocean worlds. This talk will discuss why autonomy is important for this and future missions.

Speaker: Dr. Mark Wronkiewicz, Research Data Scientist
Host: Marc Razze, Public Services Office
Co-host: Brian White, Public Services Office

JPL Family News

Retirees

The following JPL employees recently announced their retirements:

30+ Years:

Glenn Reeves, Section 3100, 38 years

Gail Woodward, Section 347N, 38 years

Mark A. Schwochert, Section 3890, 36 years

Eric B. Hochberg, Section 383C, 35 years

Passings

Dr. John D. Anderson passed away on Friday, June 24, 2022. He died of natural causes, living a long and happy life to 88. He joined the mysteries of the cosmos at peace and surrounded by his family, who noted that his onward journey coincided with a rare alignment of seven planets plus the waning Moon.

Young John David was inspired to become an astronomer by an astronomy book his grandmother gave him. Math came easily to him, and he pursued degrees in astronomy at UCLA, earning his Ph.D. in 1967.

Anderson joined JPL in 1960 and went on to become senior research scientist. He was on the Radio Science Team for many of JPL's most exciting and productive unmanned spacecraft missions of the era, including Mariners 9 and 10, Voyagers 1 and 2, Cassini, and Rosetta. He led as principal investigator on Mariners 5-7, Pioneers 5-11, Galileo, and Stardust, continuing his work as co-investigator on Juno undeterred by his official retirement from JPL in 2006.

Up to his final weeks, he continued on his own to analyze archived mission data and perform orbital determinations, "just for fun!" he would say.

For his foundational contributions to spacecraft navigation and gravity science, Anderson was awarded a NASA Medal for Exceptional Scientific Achievement in 1974 in association with Pioneer 10, and in 1999 was elected a Fellow of the American Geophysical Union.

Anderson published more than 100 articles in many professional journals, including Nature, Science, Physical Review Letters, Physics Today, Icarus, EOS, Astrophysical Journal, Journal of Geophysical Research, Celestial Mechanics, among others. In the popular press, he was interviewed for his work on Planet X and the Pioneer Anomaly, and contributed to Astronomy magazine and the Planetary Society's publications.

He held occasional visiting lecturer and researcher teaching posts at UCLA and Stanford, though his favorites were his four summers at Monash University in Australia. In addition, he mentored, supported, and collaborated with many young scientists and post-doctoral students who went on to successful research careers.

John was a lifelong model train and classical music enthusiast. He was preceded to the hereafter by his first wife, Betty, mother of his eldest three children, and by his second wife, Yuriko, whom people sometimes mistakenly called "Europa" –the Jovian moon– at Voyager and Galileo mission meetings. John is survived by his four children and seven grandchildren.

All who knew him will remember him for his gentle, unassuming demeanor, his professional generosity, and his straightforward approach to intellectual collaboration in pursuit of knowledge in the fields of gravitation and celestial mechanics.

He will also be remembered for his low-key, amiable wit: once, at a meeting, a fellow attendee introduced himself as Tim Timmerman; without missing a beat, Dr. Anderson replied, "I'm John Johnson–-nice to meet you!" He later laughed and explained to his very surprised wife that he thought Tim was making a little joke, so he merely obliged by playing along.

Willis Chapman, 67, passed away on July 29, 2022, and was well-known on the Lab for his big, infectious laugh. He was professional, smart, funny, kind, a good leader, and a genuinely nice man with an easy smile. He had a passion for golfing, fishing, dancing, and music, and loved to entertain. He was known for get-togethers where he would make gumbo – sometimes the pot was so large he would have to stir with a boat oar! On his retirement, he had hoped to make a home in a little house by a lake, or somewhere in Hawaii.

After serving in the U.S. Army from 1976-1981 and being honorably discharged, he went on to achieve his Business Administration degree in Honolulu, HI, and joined JPL in 1989 after spending time at Northrup. He worked with Richard Laser, a Special Assistant to the Director. Willis helped Richard establish the Total Quality Management Program at JPL, and from there became Deputy Manager, then Manager of Division 27. His last assignment before retiring in January 2022 was as Assistant Director for JPL Operational Strategy and Excellence, in the Business Operations Directorate.

Willis served on the Board of the Pasadena Chamber of Commerce from 2002-2010, and was Chair of the Board from 2008-2009. He was also responsible for a lot of innovation at the Chamber. It was under his leadership that the Strategic Planning process was revamped, resulting in the member services and economic development efforts becoming much more robust and meaningful. Willis was a kind and inclusive leader of people, and outstanding representative of JPL in his numerous interfaces with NASA. His primary concern was always what was best for JPL, no matter what the effect might be on his organization, as evidenced by his reorganizations of the photo lab, the print shop, and the library. He was well-respected and always willing to do whatever was asked of him, and was a force in the push at both JPL and the Caltech Credit Union to improve strategic planning.

He was definitely one-of-a-kind and will be sorely missed by many.
