National Aeronautics and
Space Administration

NASA ENGINEERING & SAFETY CENTER

TECHNICAL UPDATE

Annual Report of 2025 NESC Technical Activities

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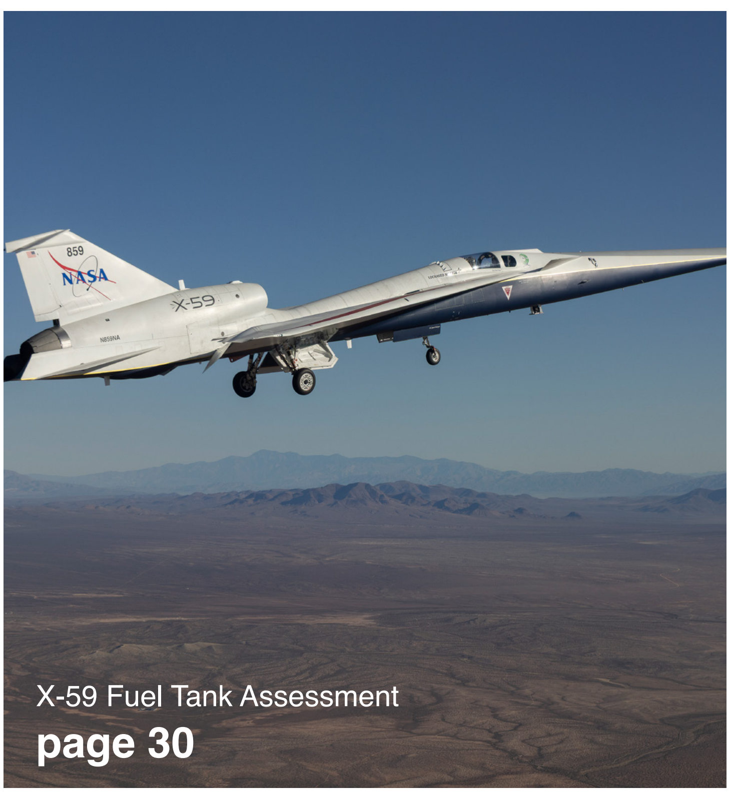

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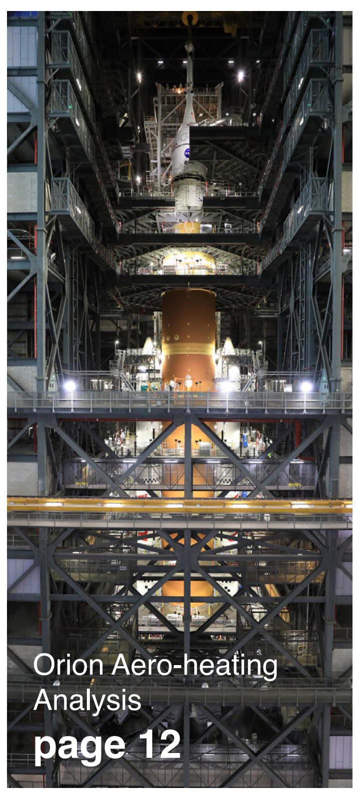

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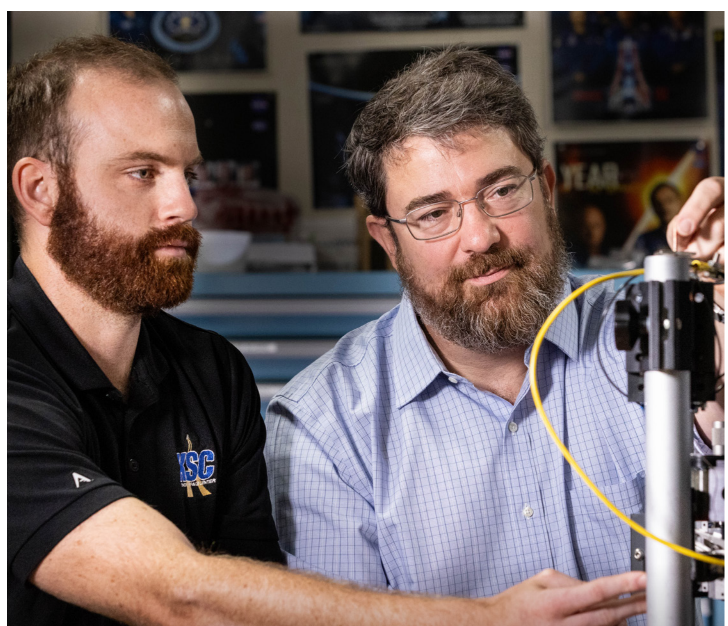

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NASA ENGINEERING & SAFETY CENTER

READY

Pre-positioned resources and experts ready to engage

INDEPENDENT

Challenging groupthink with testing and analysis, independent of programs and projects

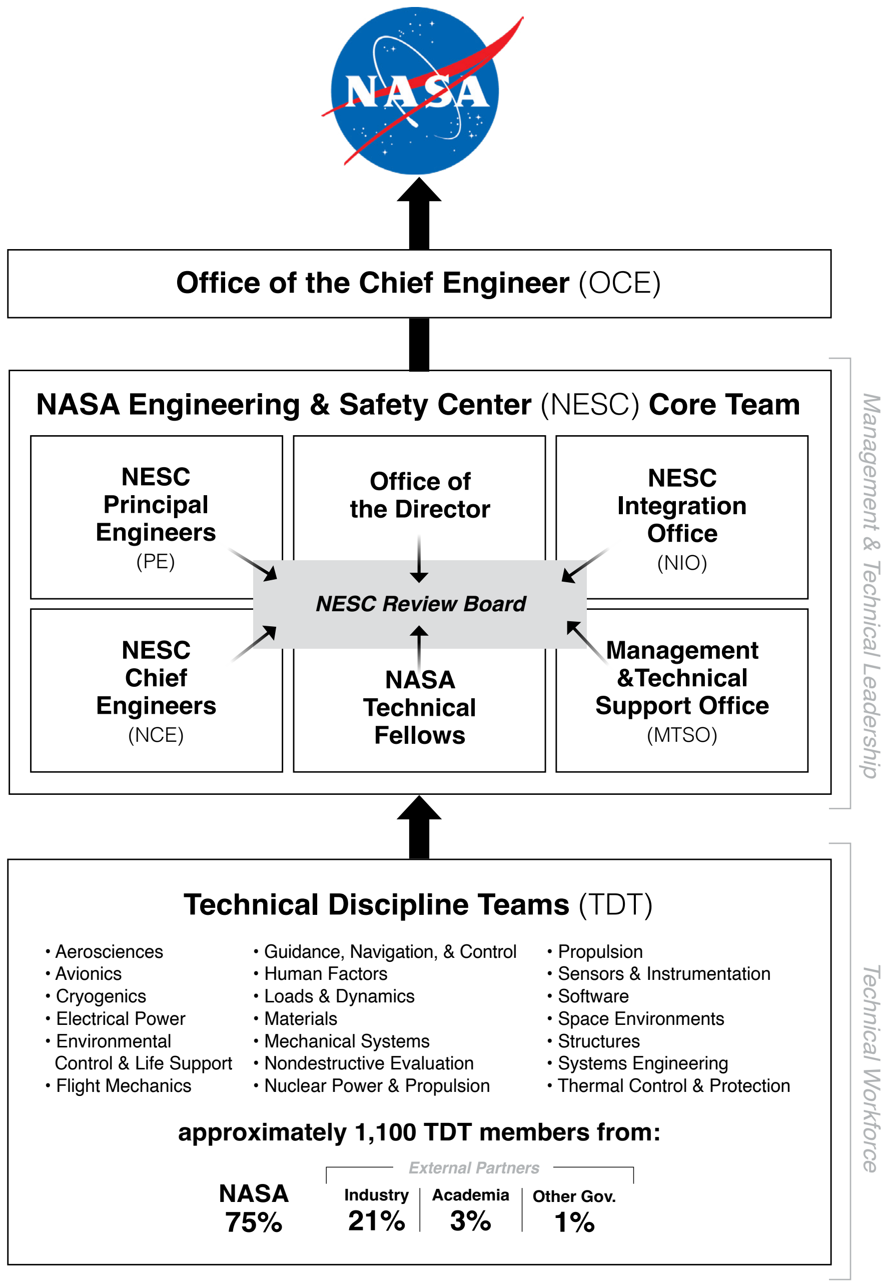
EXPERTISE

Technical subject matter experts across the country for all engineering disciplines

WHAT WE DELIVER:

Robust understanding of risk and possible risk mitigations for safety and mission success through engineering excellence

The NESC is an agency-wide resource that provides a forum for reporting technical issues and contributing alternative viewpoints to resolve NASA's highest-risk challenges. Multidisciplinary teams of ready experts provide distinctively unbiased technical assessments to enable informed decisions.



Learn more at about the NESC at
nasa.gov/nesc

MESSAGE FROM **NASA LEADERSHIP**

AMIT G. KSHATRIYA
NASA ASSOCIATE ADMINISTRATOR

When I became Associate Administrator this year, I took the position at a time of great transformation for the agency. In my 22 years at NASA, I have witnessed our team's consistent ability to adapt and drive the future of space exploration. NASA has always pursued the seemingly impossible—that is the core of our mission.

These pages highlight that persistence and resolution. The NESC was formed after the Columbia accident, when NASA faced a seemingly insurmountable return to flight. This organization directly confronted that challenge, bringing essential expertise to the table to solve problems and ensure we moved forward.

During my time with the International Space Station Program and on the agency's journey back to the Moon and Mars, I have witnessed the NESC's work firsthand. I have seen them roll up their sleeves, dig into data, schematics, and analyses, and deliver opinions and solutions. In my new role, I will continue to rely on the expertise and determination they bring to every technical challenge as we head to the Moon, Mars, and the new horizons that await us.

JOSEPH W. PELLICCIOTTI
NASA CHIEF ENGINEER

It's been an incredible year of successes at NASA with the launch of Europa Clipper, NISAR, multiple crew and resupply missions to the ISS, and with the progress we've made readying Artemis II for flight. But what amazes me the most is how we've accomplished these things amid ongoing transformation at the agency. We're busy reshaping NASA for the future and navigating the uncertainty that always comes with major change, and yet still continuing to meet our commitments to our customers and the nation.

At every center I've traveled to this year, I've seen and met people who love the work they do and who never hesitate to take on the enormous challenges that come with space exploration. It's a passion that I feel is unique to NASA and what continues to fuel our endeavors, engage the public, and excite the next generation of engineers and scientists who want to be a part of it.

Some of that passion comes through in this year's Technical Update. The NESC brings a high level of rigor, intensity, and motivation to every assessment it works, offering engineering excellence and new perspectives to our technical challenges and immeasurable value to our programs. Their reach spans NASA, industry, and the academic community. And while they often work behind the scenes, the confidence and deep understanding we gain from their assessments stands front and center with our successes. I know they will continue to meet the challenges we bring them and help the agency navigate its path to the Moon and on to Mars.

MESSAGE FROM THE **NESC DIRECTOR**

TIM R. WILSON
NESC DIRECTOR

This busy and challenging year saw significant achievements and progress as NASA advanced its mission to explore, innovate, and inspire. A highlight of the year was continuing preparation for crewed campaigns to the Moon and Mars, and a significant step in that direction will be America's return to the Moon with the Artemis II mission in 2026. NASA celebrated 25 years of continuous ISS habitation in 2025; robotic missions to study the Earth, solar system, and the universe were launched or continued; and the first flight of the X-59 low-sonic-boom aircraft took place. We were proud to contribute to NASA's accomplishments with an organization dedicated to understanding and mitigating risks associated with these missions.

The NESC is structured to provide focused technical assistance wherever needed. The strategy can be succinctly described in three words: ***ready***, ***independent***, and ***expertise***.

READY:

Fast-paced activity typical of NASA's missions requires immediate action to maintain forward momentum when problems arise. The NESC pre-positions and equips a cadre of engineers, scientists, and technicians to quickly respond to issues and hit the ground running at a moment's notice.

INDEPENDENT:

The NESC reports directly to the NASA Chief Engineer, who in turn reports to the NASA Administrator. This funding and reporting chain of command makes the NESC independent of NASA's missions, programs, and projects and shelters results and recommendations from outside influence. Alternatives not considered by the programs can be explored, and the NESC is free to focus on the technical considerations of the issues at hand.

EXPERTISE:

The NESC has access to a virtually unlimited, ready reservoir of technical expertise. NESC Technical Discipline Teams are composed of technical experts not only from the agency but from other organizations across the country. Team members come from industry, academia, and the public sector, and bring with them different perspectives and state-of-the-art knowledge in more than 20 technical disciplines.

The NESC has evolved and continues to evolve to meet NASA's objectives. This strategy and the framework required to implement it have proven successful for more than two decades while transitioning from supporting mature programs like the Space Shuttle and ISS to collaborative arrangements with new missions in development. All of NASA's mission directorates, programs, and the people who work on them have access to the NESC and its capabilities, giving the agency a unique, world-class tool to identify and mitigate technical risks. We are proud of our accomplishments in 2025 and look forward to an exciting 2026!

NESC CHIEF ASTRONAUTS:

Dr. Steven Hawley
2003-2004

Jerry L. Ross
2004-2006

Patrick G. Forrester
2009-2016

Barry "Butch" E. Wilmore
2018-2020

Scott D. Tingle
2020-2022

Mark Vande Hei
2023-present

Above: Mark Vande Hei outside of ISS (October 10, 2017).
Right: Patrick Forrester, STS-128 mission specialist, watches his spacewalking crewmates through an overhead window on the aft flight deck of Space Shuttle Discovery while docked with the ISS (September 3, 2009).

Astronauts' Perpectives on NESC Contributions to Mission Safety and Success

"...our astronaut liaisons are living, breathing reminders of why we do this work." *- Tim Wilson, NESC Director*

The exact date when the crew of Space Shuttle Columbia was lost is readily recalled by Patrick Forrester, as it likely would be for any NASA employee in service that Saturday morning when the Shuttle broke up during reentry. Forrester had flown to ISS for the first time in 2001 aboard Discovery in support of the STS-105 mission. He was scheduled to fly again shortly after Columbia's February 1, 2003 return. That date is now a somber anniversary etched in his memory.

"I had three classmates on Columbia," Forrester said. "As an astronaut class, you are even closer because you are selected together and go through that initial training together." That was the reason he said yes when asked to join the NESC in 2009 as the NESC Chief Astronaut—the liaison between the NESC and the Astronaut Office. "The NESC was started after the Columbia accident, and it was really just an honor to be part of that organization where the focus was to make sure that didn't happen again."

The NESC has had an astronaut liaison for most of its 22-year history. "It stands to reason that the individuals the NESC works so hard to protect should have a seat at the table," said NESC Director Tim Wilson. "The Chief Astronaut gives them direct access to the NESC for insight into technical activities that might affect them and a forum for voicing concerns that otherwise might not have surfaced. The interface gives us access to them as well; astronauts have lent their expertise and unique perspectives to many NESC assessments over the years. As the agency's front-line risk takers, they are by definition our primary stakeholders, and much of what we do revolves around ensuring the risks they take are well-understood and mitigated."

The current and some of the former Chief Astronauts shared their perspectives on how they feel about the NESC and whether this organization—designed to increase the overall safety of their jobs—was accomplishing that mission.

Patrick Forrester
NESC Chief Astronaut 2009-2016

It would be four years after Columbia that Forrester would fly again. That was June 2007 aboard Space Shuttle Atlantis as part of STS-117, where he helped deliver the second starboard truss and third set of solar arrays to ISS.

During his years with the NESC, Forrester assisted in NESC assessments or arranged for others from the Astronaut Office to participate. He recalled being a part of an NESC review of the astronaut pre-breathe protocol used before extravehicular activities, and he also worked with fellow astronaut Dr. Nancy Currie, who at that time was a principal engineer for the NESC, to assess the procedures and plans to ensure alternative means of return for STS-135 in the event Atlantis could not provide it. Since the other Space Shuttle orbiters had retired, rescue capability via Space Shuttle was not an option for this mission, he said. "We came up with the plan of how they could stay on the space station and use a Russian Soyuz to get them back."

continued

Forrester always felt, however, that his primary mission was to educate others about the NESC, which was a relatively new organization at that time. “I tried to help them understand that the NESC was engineering. This is what we do. This is what we need. It was one of my goals when I served: to help people understand what the NESC did.”

After leaving his NESC post to become chief of the Astronaut Office, he continued to call on the NESC during the lead-up to the launch of SpaceX Crew Dragon Demonstration Mission-2, the first SpaceX flight with crew aboard. “I was feeling the weight and the responsibility as the chief of putting Bob Behnken and Doug Hurley on that rocket for the first time. I took a lot of comfort in knowing how involved the NESC was in those decisions.”

Barry “Butch” Wilmore

NESC Chief Astronaut 2018-2020

Following Forrester’s tenure, Butch Wilmore served as the NESC Chief Astronaut for two years. A former Navy test pilot, Wilmore joined NASA in 2000, flying three missions to the ISS, including his most recent as commander of the Boeing Starliner’s first crewed flight. He took on the NESC liaison role already well acquainted with the NESC’s mission.

“I'm very familiar with the certification, flight readiness, the flight readiness reviews, and how the NESC is used to validate some of the assumptions and the engineering that takes place. And I wasn’t just aware of the organization, but knew exactly what it did and what benefit it was,” Wilmore said. “When I worked with the NESC, it gave me knowledge to understand more of what and how they went about doing things—that deep engineering analysis. And as an operator, I don't dig into the engineering analysis. I just see big picture. So, when I would see something that wasn’t right, I knew the NESC could work on it and figure out why it didn’t look right to me.”

Wilmore ended his NESC tenure when he was chosen as the Starliner commander, but continued to reach back whenever he needed answers to the multitude of questions that arise in flying a spacecraft for the first time. “Certainly when I became the commander of Starliner, there were things that I knew I wanted the NESC to have purview over.” In its support of the Commercial Crew Program, the NESC not only assisted in the lead-up to the flight, but helped troubleshoot propulsion issues it experienced on its way to ISS and with the plans to bring the crew home. “The NESC obviously has been a big help in all organizations,” Wilmore added. “I think that the role it plays is vital, and I wish it was larger.”

Scott Tingle

NESC Chief Astronaut 2020-2022

Scott Tingle was selected in June 2009 to the astronaut corps, serving as a flight engineer and U.S. Operational Segment Lead for Expedition 54/55, where he spent 168 days aboard the ISS. His training for spaceflight involved many discussions about the Columbia accident.

“We debriefed it 100 times,” he said. “When we’re talking safety issues—Apollo, Challenger, Columbia—they always come up, and there are always really good lessons learned.”

With his naval aviation and engineering background, Tingle said it didn’t take him long to get a feel for how the NESC worked. “They really get their fingers on the pulse of operations, which is what I think is one of the high value things they do.” When it came to filling in engineering gaps, Tingle liked having the NESC to lean on, “not only because of their engineering perspective, but because it’s independent. They're not involved in the politics and everything that goes with it. And they have the end user and the operators in their heart and soul,” said Tingle. “This is the product that you get out of the NESC. It's just a huge value because of that.”

“Having folks able to dive into the technicals, it really helps us. And it doesn't just help us, it helps the crew, it helps the program, it helps the contractors, it helps our technical authorities. It helps everybody just to have people with that capability.”

He remembers when the NESC ramped up material testing to address an issue the astronaut corps was working. “They were able to get results very quickly. They really do fill the gap when it needs to be filled. They help us catch the things that we can't catch.”

Being an astronaut was always on Tingle’s career agenda, and that obsession was deeply rooted at an early age. “I remember watching on TV Neil Armstrong stepping out onto the moon. I was four years old at the time, and me and my mom were watching in our living room.”

In a way, that is part of what he thinks makes the NESC so valuable. “They have not forgotten their roots. They haven’t forgotten the users who actually use this equipment and the value of the overall human spaceflight community.”

Sometimes that value is only seen in hindsight. “When we finally get up and running with all of these vehicles, I think you're going to be able to go back and list all of these actions the NESC supported and how they helped provide critical information. You're going to end up seeing that, ‘Wow, this was really transformational. This really helped us with our overall direction. It helped us be successful,’ ” Tingle said. “I'm honored to have been a part of it.”

Mark Vande Hei

NESC Chief Astronaut 2023-present

“I think the fact that NASA's been willing to invest the talent and the resources to have an organization that can do a really deep dive with a second, third, fifth set of eyes, with the best technical experts and the perspective of knowing what’s going on across NASA, is a hugely beneficial thing,” said Mark Vande Hei, the current NESC Chief Astronaut.

Relatively new to the organization, he’s been getting up to speed. “I’ve already seen programs like the ISS repeatedly pull in NESC expertise to help out.” In his own experience, he

sought NESC advice to help understand the risk posture associated with batteries. "I knew it was something we could fix, but it was going to cost money. And so the emphasis was on 'how risky is this? Can we accept this risk?' " Help from the NASA Technical Fellow for Electrical Power helped him make decisions on what avenues to pursue.

He also asked the NESC to convey the risks associated with leaks in the Russian PrK module. "I wanted to have both sides hear directly what the other's perspective was. I was impressed with the NESC's professionalism," said Vande Hei, in discussing a topic that has been controversial at times. "In addition to their technical skills, there's an impressive interpersonal skill set that comes along with the folks on the NESC, too."

Having already spent more than 500 days in space, Vande Hei is focused on the next generation. "There are a lot of other people who haven't flown yet, and we need to get them to space because they'll still be around when we're doing much more challenging missions to the Moon and Mars. And they need to get the experience to be ready for those things much more than I do." Even today, Vande Hei said the emotions he goes through when he watches astronauts launch, "I'm a mess. It's rough, but it's great. I call it 'horribly amazing.' "

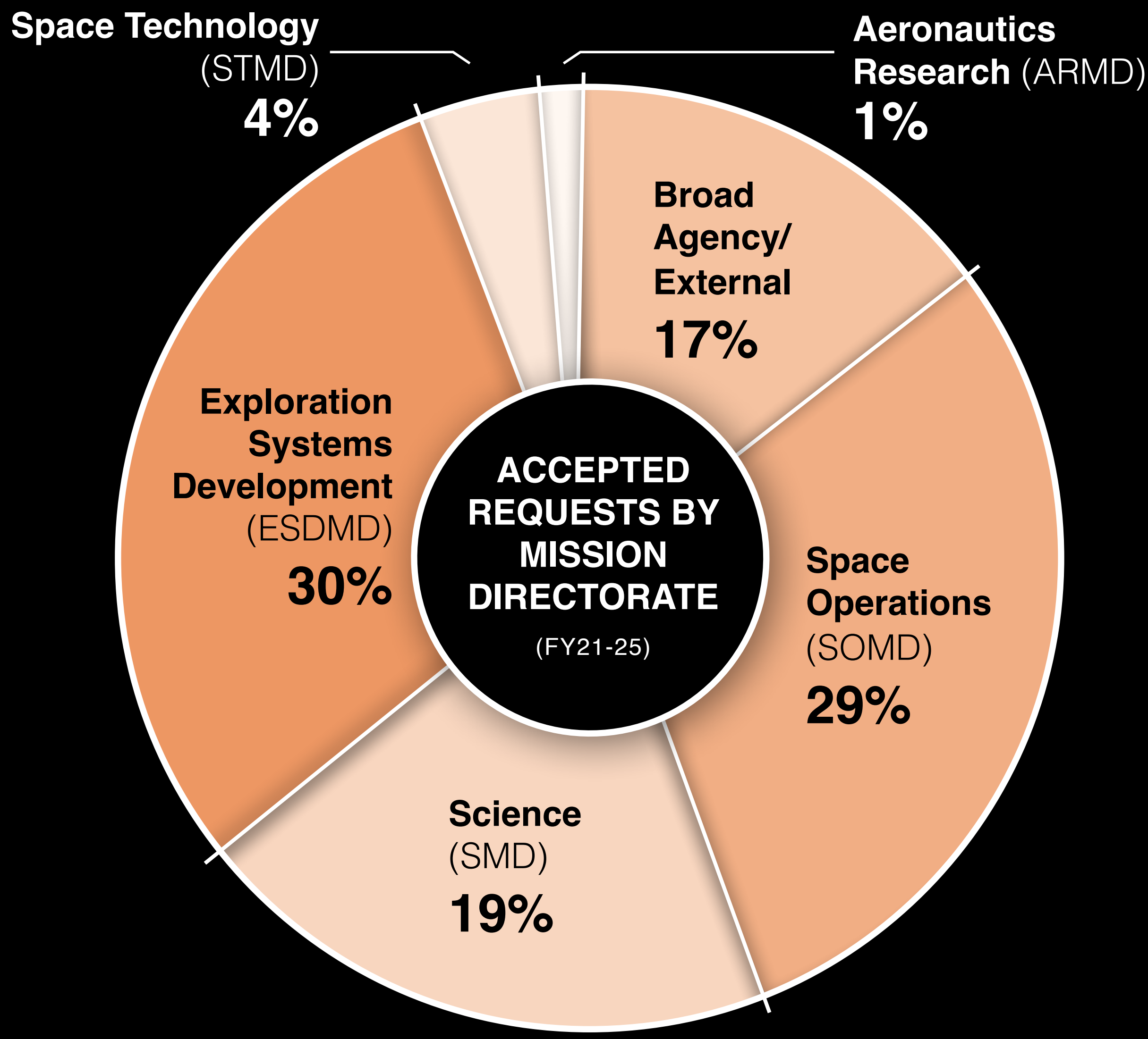
Today, 22 years in and with nearly 1,400 assessments behind it, the NESC has won the respect of the programs and projects it supports, and some of it was earned with the help of its astronaut liaisons. "They helped us prove we could add value to NASA missions and bring new perspectives to their technical problems," said Wilson. "We keep a photograph of the Columbia crew in the NESC office, but our astronaut liaisons are living, breathing reminders of why we do this work."

Pat Forrester, now retired from NASA, considers his time with the NESC well spent. "You always want to be able, if there is an accident, to look at the remaining family and let them know you did everything that could be done. The amount of involvement the NESC has is limited only by funds and people, so I know how hard everyone works on those assessments," he said. "I appreciated it so much when I was in that role where I felt like I was carrying a lot of the burden." ●

Top: Boeing Crew Flight Test Commander Butch Wilmore performs spacesuit maintenance inside ISS's Quest airlock (July 11, 2024). **Middle:** Scott Tingle wears a U.S. spacesuit inside the Quest Airlock preparing for his first spacewalk (January 18, 2018). **Bottom:** Expedition 65 Flight Engineer Mark Vande Hei works inside the U.S. Destiny laboratory module's Microgravity Science Glovebox for the Ring Sheared Drop fluid physics study (August 16, 2021).

NESC TECHNICAL ACTIVITIES

NESC technical activities reach across mission directorates and programs encompassing design, test, and flight phases.



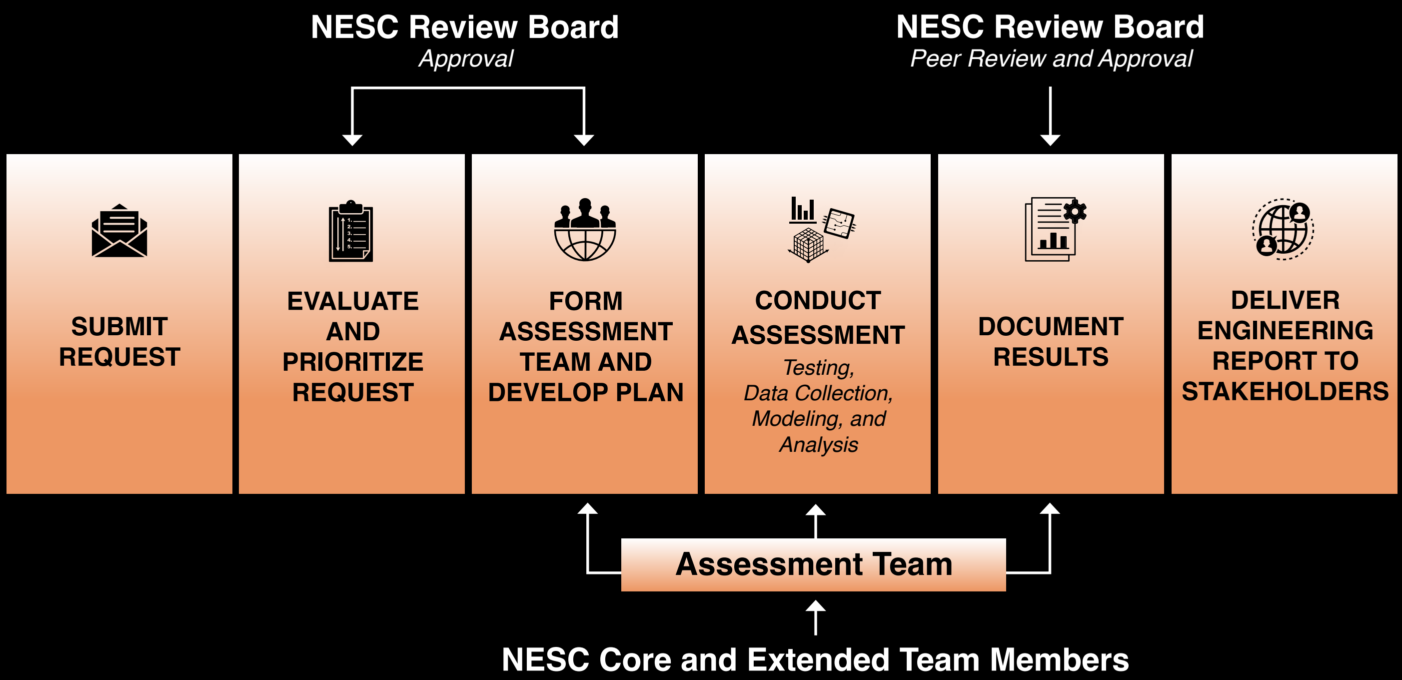
(as of September 30, 2025)

- **1,397** Total Accepted Requests *(since 2003)*
- **84** Accepted Requests in FY25
- **64** Accepted Requests Yearly Average *(2004-25)*
- **149** In-progess Requests

NESC ASSESSMENT PROCESS:

The NESC assessment process is key to developing peer-reviewed engineering reports for stakeholders.

Requests for technical assistance are evaluated by the NESC Review Board (NRB). If a request is approved, a team is formed that will perform independent testing, analyses, and other activities as necessary to develop the data needed to answer the stakeholder's request. An NESC team's findings, observations, and recommendations are documented within an engineering report and are peer reviewed and approved by the NRB prior to release to the stakeholder.



EXPLORATION SYSTEMS DEVELOPMENT
NESC TECHNICAL ACTIVITIES

COMPLETED IN FY25:

Understanding Risks that Come with Lunar Habitation

The design and development of a pressurized rover (PR) for traversing the lunar surface is a multi-faceted challenge as the vehicle must operate as a mobile habitat, transporting and protecting astronauts as they explore the Moon away from their lunar home base. Given the many challenges that could arise during exploration activities, the NESC was asked to help characterize the risk of having an inoperable suit during a PR lunar surface operation in order to identify, prepare for, and mitigate potential risks.

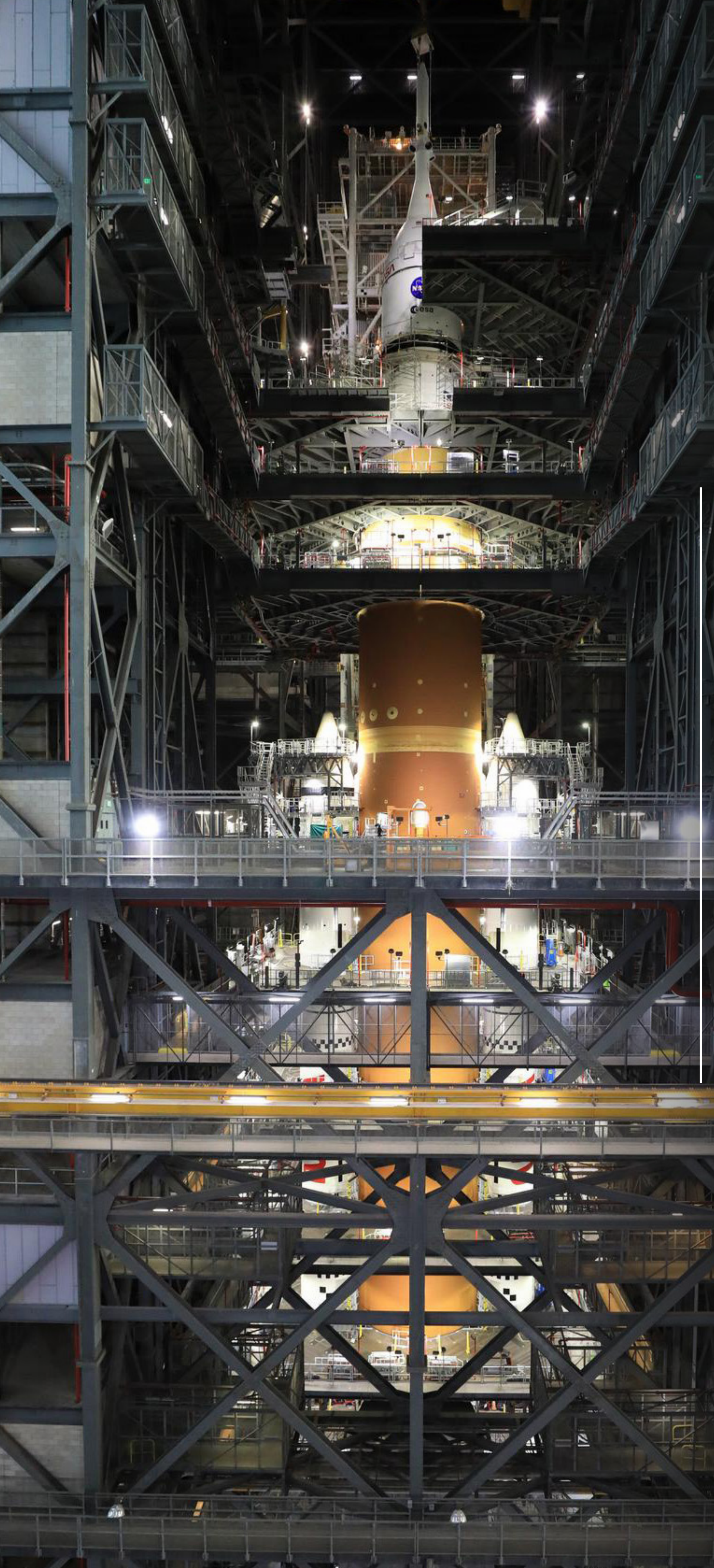
The NESC team first identified credible failures for suit and intravehicular activity hardware for an Artemis VII mission scenario, when a PR is first scheduled for use on the Moon. Historical suit component failures, close calls, mishaps, and hardware malfuntion data from Apollo, Space Shuttle, and ISS were analyzed by the team in the context of the PR mission scenario. The team also factored in certain constraints, such as depressurization and repressurization of the PR cabin and crew spacesuits during operations. The results of the assessment helped identify spacesuit design considerations as well as critical spare parts that if carried on the PR would help reduce risk for Artemis crews. This work was performed by Marshall and Langley.

A concept image of the back of a pressurized rover on the surface of the Moon with the airlock in view. Image Credit: JAXA/Toyota

IN-PROGRESS:

Orion Aero-heating Analysis

The NESC worked with subject matter experts from Langley and the University of Minnesota to assist the Orion Program with an independent analysis and state-of-the-art computational fluid dynamics calculations to better capture the aero-heating environments around the crew module's retention and release mechanism. The mechanism is part of the Artemis II as-built hardware.



The Orion spacecraft for the agency's Artemis II mission is secured on top of the SLS rocket in Kennedy's Vehicle Assembly Building.

IN-PROGRESS:

Mars Crew Vicinity Workload Modeling

Building on NESC trade-space-analysis modeling of proposed Mars crew sizes, missions, and scenarios, the NESC is assisting the NASA Mars Architecture Team with developing a new force-level model of Mars vicinity operations (with extravehicular and intravehicular crew duties delineated) to more tightly couple the overall Mars manpower analyses.

Artist's concept of astronauts and human habitats on Mars.

IN-PROGRESS:

Screening Materials for Flammability in Lunar Gravity

The NESC is working with the Human Landing System and Extravehicular Activity and Human Surface Mobility Program to conduct testing and analysis on the flammability of materials when subjected to lunar gravity. The work is part of the NESC's effort to help them develop screening and acceptance methods for nonmetallic material flammability in low-gravity environments.

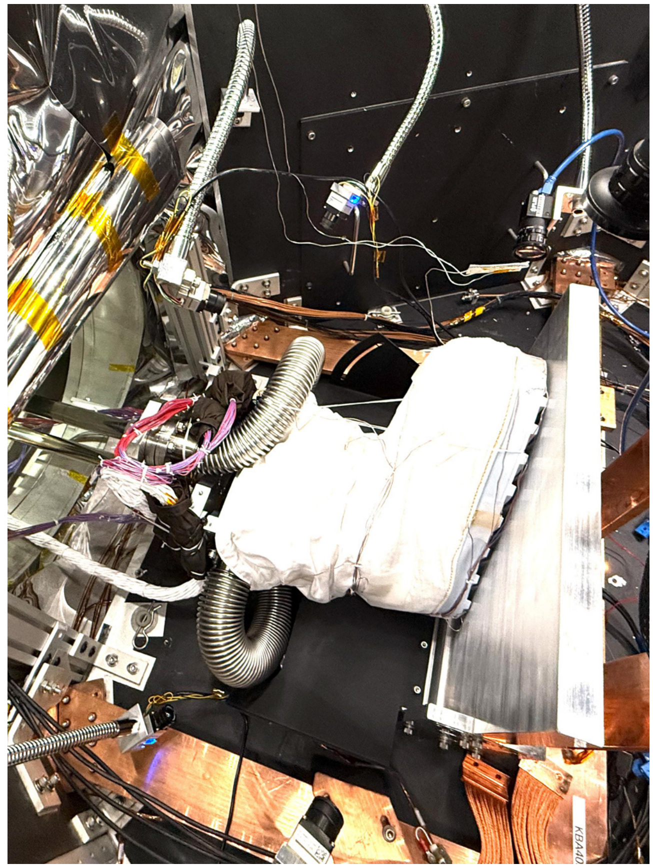
The NESC team used Glenn's Zero Gravity Facility during its flammability testing, which included the drop tower, which drops a self-contained experiment vehicle 432 feet through a vacuum shaft to generate 5.18 seconds of microgravity. The vehicle is caught at the bottom by a bucket of polystyrene beads to slow the impact.

COMPLETED IN FY25:

Ensuring Artemis Boots Withstand Extreme Cold of Lunar Surface

As NASA works with industry providers to develop spacesuits for Artemis lunar surface missions, the NESC has been providing expertise when needed. Leveraging its previous work on a lunar glove thermal and durability assessment, an NESC team made up of JPL and North Carolina State University (NCSU) recently supported the Extravehicular Activity (EVA) Development Project at Johnson Space Center under the EVA and Human Mobility Program on lunar spacesuit boot development. The aim was to develop a test method to evaluate thermal performance in the extreme environments on the Moon, where the permanently shadowed regions can reach temperatures lower than -370°F.

The NESC provided expertise to advise on the development of a thermal foot manikin and test methods, and performed tests in JPL's thermal vacuum chamber. Work also included ASTM standard development and statistical analysis. The new test approach was demonstrated to be repeatable, and the test series provided substantial data to allow for correlation of the boot thermal model. This work was performed by JPL, Johnson, and NCSU.

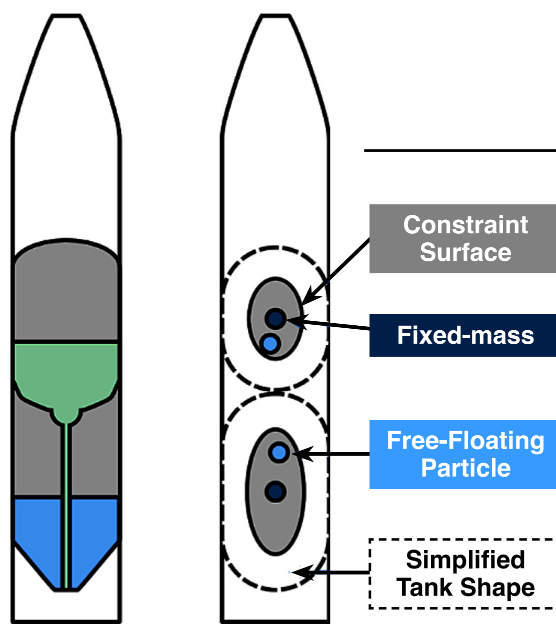


A boot that's part of a NASA lunar surface spacesuit prototype is readied for testing inside a thermal vacuum chamber called CITADEL at the agency's Jet Propulsion Laboratory. The thick aluminum plate at right stands in for the frigid surface of the lunar south pole, where Artemis III astronauts will confront conditions more extreme than any previously experienced by humans.

IN-PROGRESS:

HLS Low-g Slosh Modeling Support

The NESC developed, calibrated, validated, and implemented low-gravity slosh models for the Human Landing System and the Multi-Purpose Crew Vehicle service module to aid in advancing the state of low-gravity slosh modeling and quantifying the impacts of propellant movement during events such as propellant transfer, separation, and docking in low-gravity environments.



Low-g Slosh Particle Model Schematic

The particle model is a simplified mechanical representation of propellant slosh dynamics, using two lumped-mass particles—one fixed and one free-moving—to approximate fluid motion. The free particle moves within an ellipsoidal constraint surface, simulating slosh-induced forces on the spacecraft.

SPACE OPERATIONS
NESC TECHNICAL ACTIVITIES

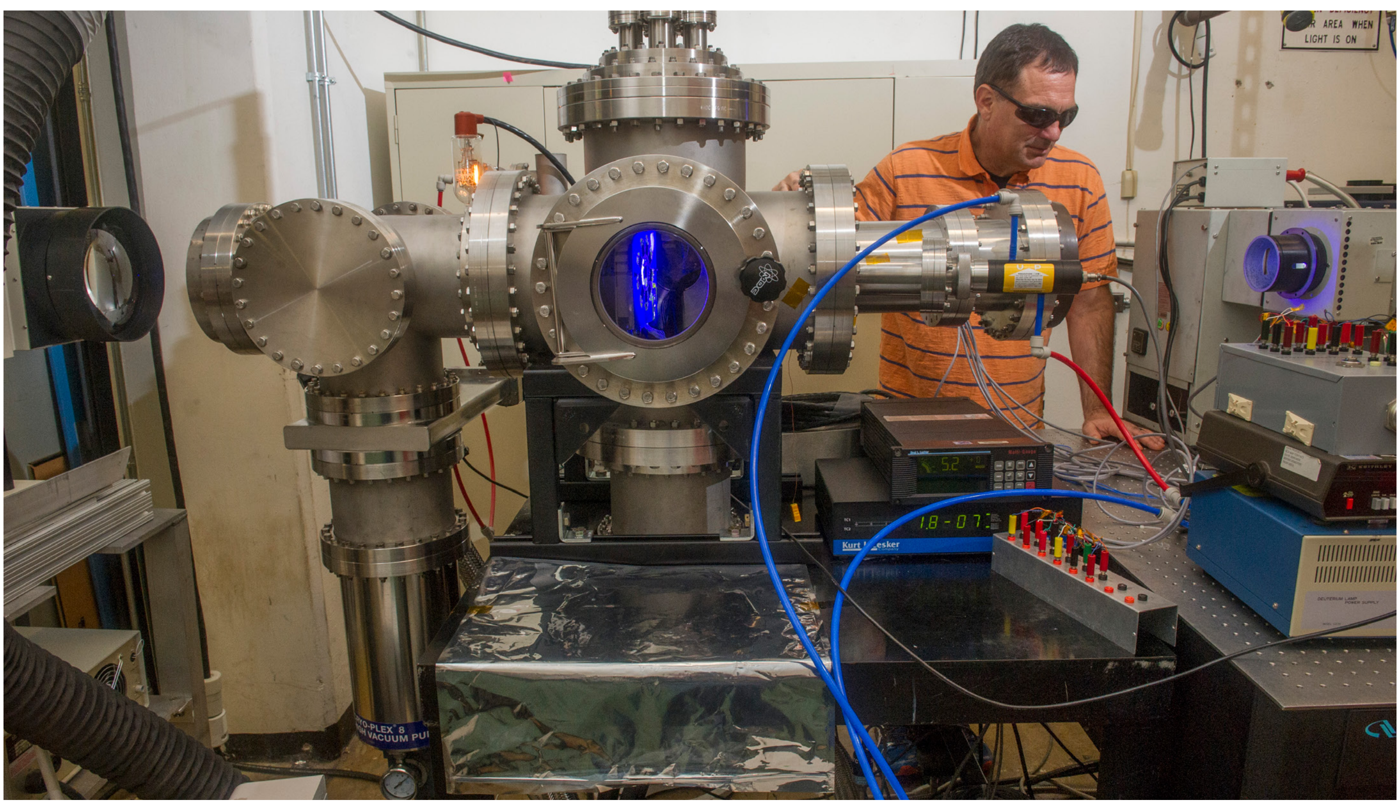
COMPLETED IN FY25:
Understanding In-flight Paint Degradation

Engineers use special thermal-control coatings to keep a spacecraft within a safe temperature range. Coating properties such as solar absorptivity (how much solar spectrum energy the surface absorbs) and infrared emissivity (how well the surface absorbs and radiates infrared energy), along with heat from inside the spacecraft and other outside sources, determine how hot or cold the spacecraft gets. However, in low Earth orbit, these coatings can wear down or darken over time due to exposure to the Sun's ultraviolet (UV) rays, making it challenging to choose a coating that will last and perform well. This year the NESC assisted the Commercial Crew Program (CCP) Materials & Processes group in understanding UV-induced degradation of silicone-based thermal control coatings. The NESC reviewed flight, ground test, and published data on UV-induced degradation and found that bakeout plays an important role in this degradation, indicating that UV interaction with paint volatiles, and not the structural material, is the primary source of coating discoloration. The team determined that prebake or in-flight continuous baking decreases thermal paint discoloration (darkening), which is an important factor for spacecraft thermal control. This work was performed by JPL, Langley, Marshall, Goddard, and Kennedy.

REFER TO TECHNICAL BULLETIN 25-01

The Need to Bake Out Silicone Based Thermal Control Coatings

nasa.gov/nesc



A UV exposure facility at Marshall Space Flight Center.

COMPLETED IN FY25:

Understanding Injury Risk through Human Testing

NESC human factors experts, in collaboration with commercial partners and the Orion Program, conducted human impact testing to increase the understanding of injury risk from landing and demonstrate the predicted safety for the crew. All NASA crewed vehicles are designed to meet occupant protection safety requirements, including the Brinkley Dynamic Response Criterion and Anthropomorphic Test Device (ATD) limits, but these tools have limitations. The NESC assessment added human volunteer impact testing that while outside the certification requirements, revealed injury responses that were too low and too sensitive for ATDs to capture.

Tests were conducted at Wright-Patterson Air Force Base using the most flight-like hardware available at the time. While ATD tests met requirements and did not predict major injuries, human tests provided insights into minor injuries and discomfort. Subjects reported 17 issues not evident in ATD tests, and multiple observations were made on bracing effectiveness and seat fit. These tests, done in a controlled environment, allowed for improvements before flight. Lessons learned will enhance the design and operations of U.S. vehicles, improving crew safety. Human testing is crucial for understanding a broad range of injury risks during landings. This work was performed by Ames and Johnson.

A U.S. Air Force volunteer tests a flight suit and seat for the Orion crew module in the drop tower facility at Wright-Patterson Air Force Base, Ohio. Photo credit: U.S. Air Force photo/Richard Eldridge

IN-PROGRESS:

Triboelectric Effects on Launch Vehicles and Spacecraft

The NESC is taking a comprehensive look at triboelectric effects on launch vehicles and spacecraft for CCP, including the foundational physics associated with triboelectrification and how ethernet false carrier anomalies may be linked to these effects.

Today's Launch Vehicles

Left: SpaceX Falcon Heavy carrying NASA's Europa Clipper.
Center: SpaceX Falcon 9 carrying the Dragon spacecraft with NASA's SpaceX Crew-11.
Right: United Launch Alliance Atlas V with Boeing's CST-100 Starliner spacecraft.

In October 2009, the NASA's Ares 1-X launch attempt was scrubbed because of weather and the potential for triboelectric effects, caused when ice particles, dust, or water droplets collide with the vehicle's surface, causing frictional contact that transfers electrical charge.

IN-PROGRESS:

Energy Modulator Testing

The NESC is assisting CCP in tests of energy modulators, widely used in parachute systems to control shock loads experienced during various stages of parachute system deployment. Testing, performed at the Langley Impact Dynamics Facility, involves a previously developed method that releases a swing mass, pendulum style, to impart significant kinetic energy into critical components.

COMPLETED FY25:

CCP Parachute and Airbag Statistical Support

The NESC provided statistical analysis for a CCP parachute suspension line and landing airbag material allowables and helped determine the best method for assessing the data. The team evaluated the methodology in the Composite Materials Handbook-17 framework (used by industry, government, and academia to standardize data development, validation, design, and certification). In addition, candidate statistical distribution models appropriate for use in reliability, materials, and failure analysis were developed and compared to determine which method best characterized the parachute and airbag data. Analysis was also conducted to assess whether data from multiple missions should be combined when calculating the material allowables. This work was performed by Langley.

IN-PROGRESS:

Parachute Design Guidelines Revision

NESC updates to the T.W. Knacke "Parachute Recovery Systems Design Manual," used by CCP, will add decades of advancements in testing, materials, and analysis to this historical technical resource and ensure the safe design of future systems.

The SpaceX Crew Dragon Endurance spacecraft lands in the Pacific Ocean off the coast of San Diego, California, on August 9, 2025.

IN-PROGRESS:

Assisting CCP with Engine Hardware Analysis

NESC materials experts are assisting CCP in analyzing rocket engine hardware to determine the mechanisms that can cause titanium-nitrogen tetroxide (Ti-NTO) spots in engine dome material. The work involves identifying potential causes as well as integrated test and analysis to determine the risk of dome-material ignition.

COMPLETED IN FY25:

Understanding Hot Gas Intrusion Sources

To help CCP determine the possible sources of hot gas or flame intrusion (HGI) into launch vehicle engine bays, the NESC looked at the flight hardware configuration, materials and processes, and propulsion system performance for vulnerabilities that could allow hot and flammable recirculated plume gas to enter and the sources of oxygen that could augment a combustion event. Hazards from HGI sources can damage critical components such as wiring harnesses, structural elements, pressure walls, aerosurfaces, and seals, affecting their margins of safety over time. The team looked at both internal, external, and combinations of HGI sources, operating conditions that could increase the probability of hot gas entry, and the risks associated with them. The team also identified key locations that may induce flight-critical hardware damage, areas susceptible to incremental degradation over multiple missions, and potential maintenance, design, and operational mitigations and augmented the understanding of the performance of the protective hardware through hot-gas testing of coupons at Marshall. This work was performed by White Sands Test Facility, Kennedy, Marshall, JPL, Langley, Johnson, and Goddard.

A significant and recurring source of HGI is the launch vehicle's external engine plume recirculation. Other potential sources include atmospheric gases entering closed spaces and internal leakage of a gas or a combustion event from flammable gas ignited in the presence of sufficient oxygen.

COMPLETED IN FY25:

New Methodologies for Measuring the Velocity of Detonation in Explosive Cords

NASA uses flexible confined detonating cords (FCDCs) on spacecraft to allow a detonator to remotely initiate separation of spacecraft structures, to release hold-down bolts, and other events that require the ignition of explosive items. A typical FCDC provides detonation transfer from one end to the other. Aging flight lots of FCDCs must be periodically tested to ensure that their materials have not degraded over time and are still viable for use in flight. The current testing approach can be difficult and involves manually cutting notches into the cable and placing ionization sensors to track the velocity of detonation (VOD). However, this practice can damage the unit undergoing testing. To assist CCP in finding a different method for determining the VOD of aging explosive cords, the NESC researched and compared other methods that would eliminate the need for notching or nicking the metallic sheath of the FCDC. Following the release of the NESC results, Johnson began qualification testing of the NESC's leading recommended method—piezoelectric sensors—which appears to meet requirements with improved accuracy, lower cost, and no risk of damaging the unit under test. After extensive testing, the new approach was accepted and has replaced the older method. This work was performed by White Sands Test Facility, Langley, and Johnson. NASA/TM-20240012669

NASA's Europa Clipper spacecraft separates from the Falcon Heavy second stage after launch on Monday, October 14, 2024, from Kennedy.

IN-PROGRESS:

Material Sensitivities to N_2O_4/MON Exposure

The NESC is conducting coupon-level testing of materials to determine their sensitivities to nitrogen tetroxide (N_2O_4) and mixed oxides of nitrogen (MON) exposure in relevant environmental conditions. The work addresses compatibility-related issues and material exposure testing gaps that date back to the Apollo Program.

A technician at White Sands Test Facility removes test coupons from ovens during a coupon-exposure study.

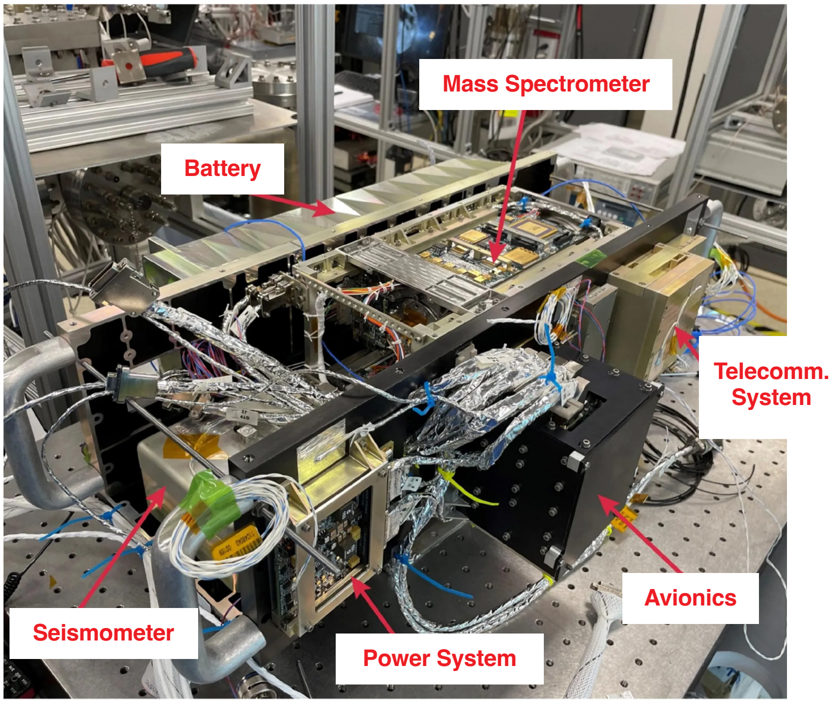
SCIENCE
NESC TECHNICAL ACTIVITIES

COMPLETED IN FY25:
Protecting the LEMS from Plume Damage

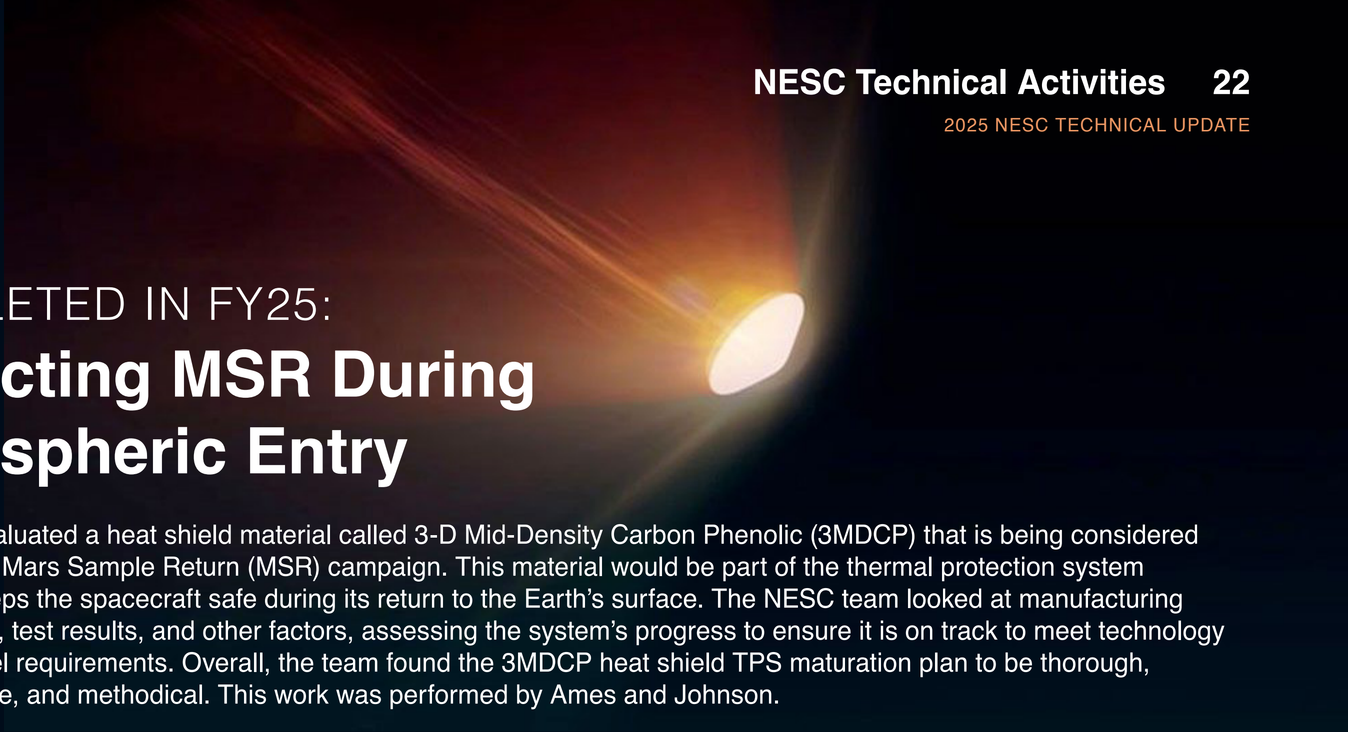
During Artemis III, astronauts will deliver and install the Lunar Environment Monitoring Station (LEMS) near the landing site at the lunar south pole. LEMS, about the size of a small suitcase, will house seismometers that will monitor lunar seismic activity. The polar location requires the instruments to have multilayer insulation (MLI) to survive a 14-day lunar night. However, the MLI will be exposed to high-speed particles of lunar regolith disturbed by the ascent plume from the Human Landing System (HLS). To protect LEMS, the extravehicular activity (EVA) concept of operations could require installation at increased distance from the HLS or additional worksite protective accommodations—both of which present complications and likely increased EVA time.

The LEMS Project requested the NESC's help in simulating the damage to MLI design options to determine the best MLI layup to meet thermal requirements and ensure adequate robustness to plume damage. The NESC used hydrocode simulations to model the damage to the LEMS MLI from the HLS ascent plume, using the results to determine the expected damage to the existing MLI configuration and possible mitigations such as adding additional layers of material or adjusting the LEMS placement in relation to the HLS. Based on these data, the LEMS Project chose to add a 16 mil Nextel blanket to protect the MLI. This work was performed by Langley.

LEMS is a compact suite of seismometers, about the size of a carry-on suitcase, designed to continuously monitor the Moon's surface for ground movement caused by moonquakes. Both meteoroid impacts and a shrinking and cooling moon cause the lunar surface and subsurface to shake.



LEMS engineering unit during integration at Goddard. This LEMS prototype incorporates a compact mass spectrometer provided by Goddard and a broadband seismometer provided by the University of Arizona. The unit's avionics manage its power and thermal states and initiate monthly communication sessions with ground stations on Earth to transmit collected data.

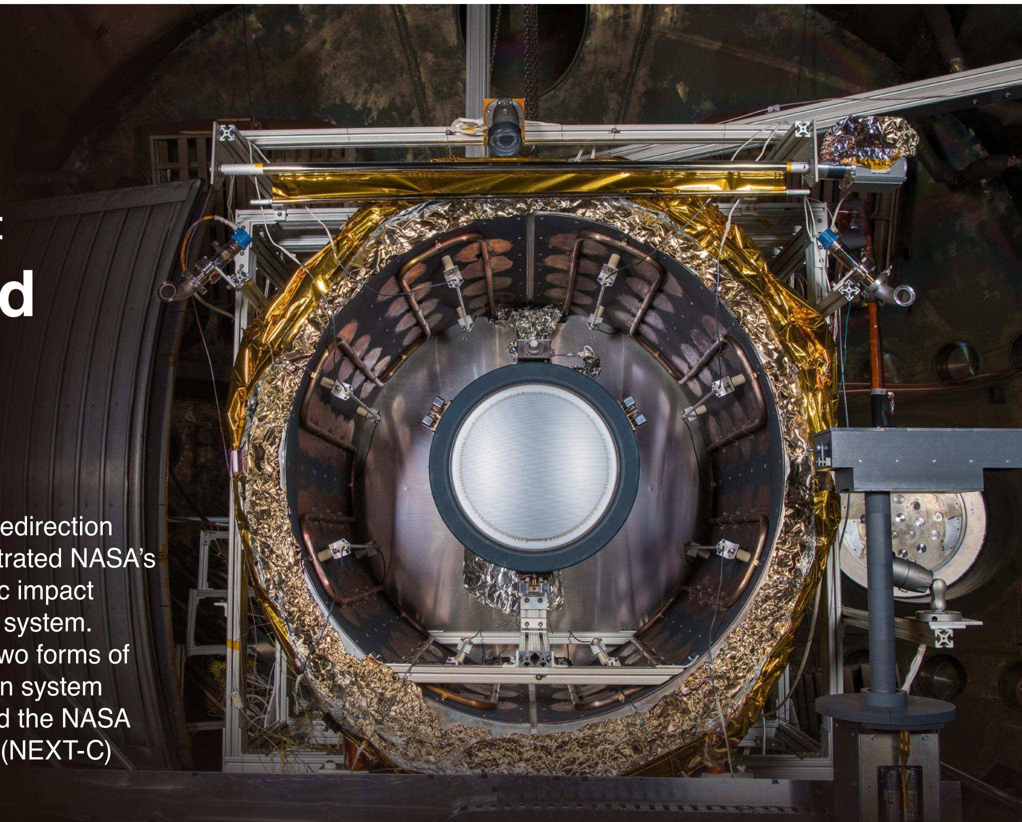


COMPLETED IN FY25:

Protecting MSR During Atmospheric Entry

The NESC evaluated a heat shield material called 3-D Mid-Density Carbon Phenolic (3MDCP) that is being considered for use on the Mars Sample Return (MSR) campaign. This material would be part of the thermal protection system (TPS) that keeps the spacecraft safe during its return to the Earth's surface. The NESC team looked at manufacturing developments, test results, and other factors, assessing the system's progress to ensure it is on track to meet technology readiness level requirements. Overall, the team found the 3MDCP heat shield TPS maturation plan to be thorough, comprehensive, and methodical. This work was performed by Ames and Johnson.

Artist concept of the MSR Earth Entry System with a heat shield for safe entry through the Earth's atmosphere. NASA is evaluating a new heat shield technology to protect future missions during atmospheric entry. These new TPS systems are three-dimensional, woven composite heat shields capable of significantly reducing entry loads and lowering the mass of heat shields. The woven materials have blended carbon/phenolic filament tows and a phenolic resin matrix.



COMPLETED IN FY25:

Lessons Learned from the DART Mission

In September 2022, the Double Asteroid Redirection Test (DART) mission successfully demonstrated NASA's planetary defense capabilities with a kinetic impact of the binary asteroid Didymos/Dimorphos system. The DART spacecraft was equipped with two forms of in-space propulsion—a chemical propulsion system and an electric propulsion system that used the NASA Evolutionary Xenon Thruster–Commercial (NEXT-C) gridded ion technology.

During the mission, avionics anomalies forced the early shutdown of the NEXT-C thruster. The NESC formed a joint team of power, avionics, space environments, and propulsion experts to review the DART and NEXT-C designs and mission data. The team identified flaws in the avionics design that became susceptible to the thruster electromagnetic emissions and developed testing recommendations to prevent similar anomalies in future missions. Additionally, the team provided regular briefings of preliminary findings to the Gateway Program and its Power and Propulsion Element given its planned use of electric propulsion. This work was performed by Kennedy, Johns Hopkins University Applied Physics Lab, Glenn, JPL, Marshall, Goddard, and Langley.

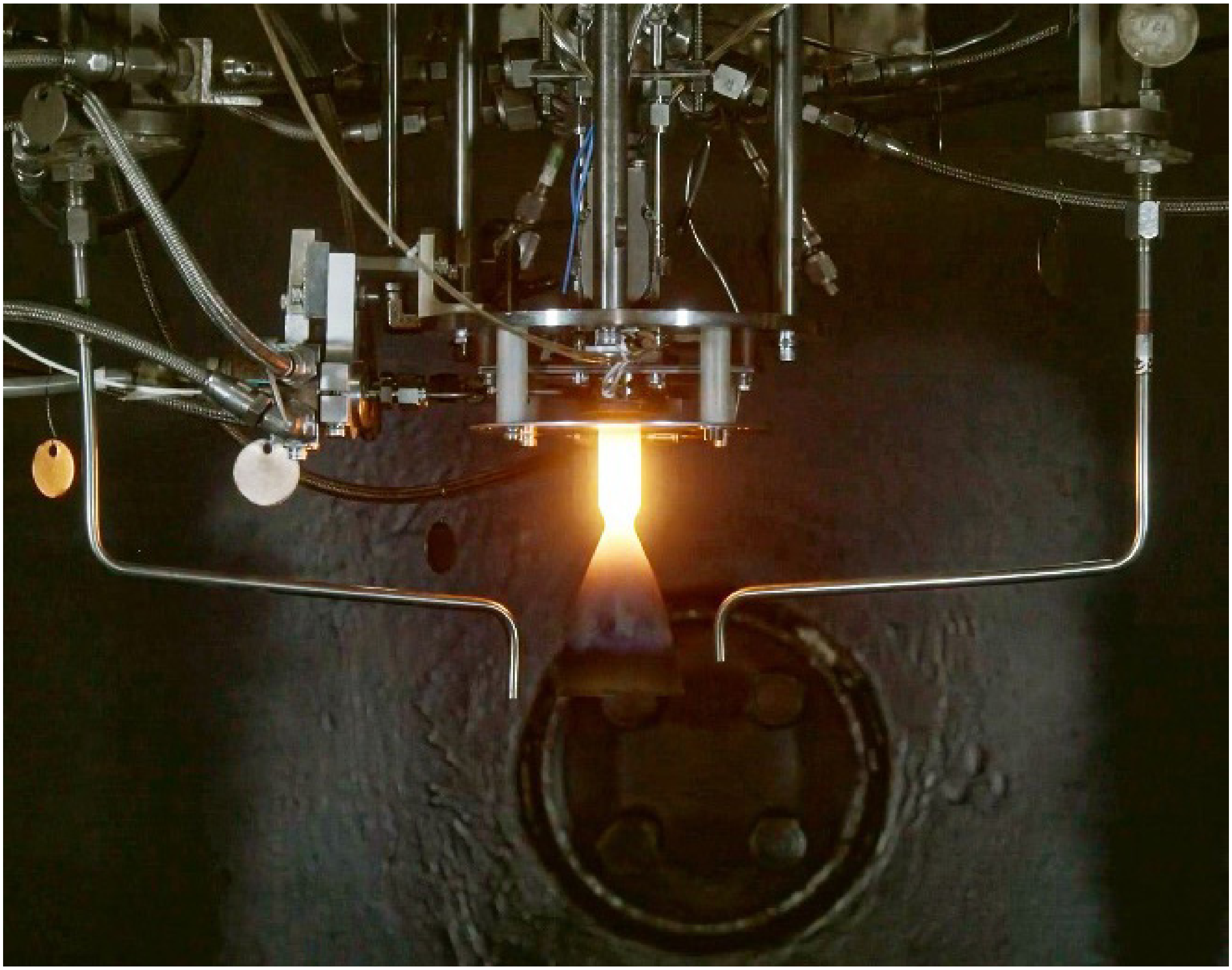
NASA Evolutionary Xenon Thruster - Commercial, NEXT-C

BROAD AGENCY/EXTERNAL
NESC TECHNICAL ACTIVITIES

IN-PROGRESS:

Hot-Fire Testing of Reaction Control System Thrusters

The NESC is working with the Gateway Program on a reaction control system (RCS) thruster test campaign designed to understand the capability of these thrusters under "Gateway-like" operations, which uniquely include multiple refuelings. The testing is geared toward the 24 Moog 5-lbf class thrusters to be used on Gateway's Power and Propulsion Element.



An RCS thruster undergoes testing at a Moog facility. Photo provided by Moog, Inc.

COMPLETED IN FY25:

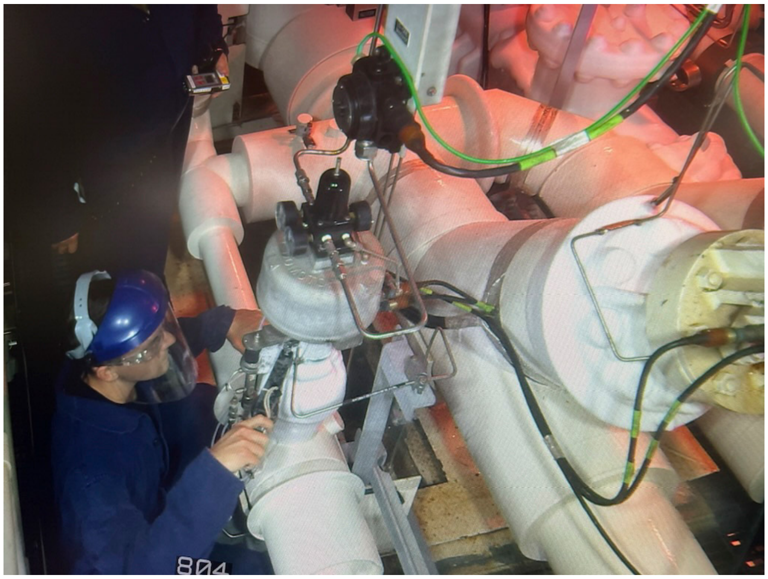
Reducing Risk in Self-reacting Friction Stir Welding

The NESC characterized and developed approaches to mitigate self-reacting friction stir weld (SRFSW) anomalies found during weld process qualifications at NASA. The qualification specimens exhibited reduced tensile strength and elongation in what was originally attributed to a flat, low ductility low topography (LDLT) fracture feature anomaly.

The NESC used advanced data analytics and statistical approaches, established machine-learning analysis algorithms, and developed physics-based process models that improved understanding of the process-microstructure-property relationships in SRFSW, and correlated process inputs that resulted in reduced mechanical properties not associated with LDLT phenomena. As a result, the NESC recommended new process input parameters and post-weld surface preparation processes to mitigate the risk of reduced mechanical performance.

For more information on the team's work, see the related Innovative Technique article on page 55. This work was performed by Kennedy, Glenn, Marshall, and Johnson. NASA/TM-20240016466, NASA/TM-20230010624

Technicians used friction stir welding to join the aft dome of the SLS liquid oxygen tank to the previously joined forward dome and aft barrel segments at NASA's Friction Stir Welding lab at the Michoud Vertical Assembly Center. The dome will form part of the core stage that will power NASA's Artemis III mission.



IN-PROGRESS:

NASA Valve Standard

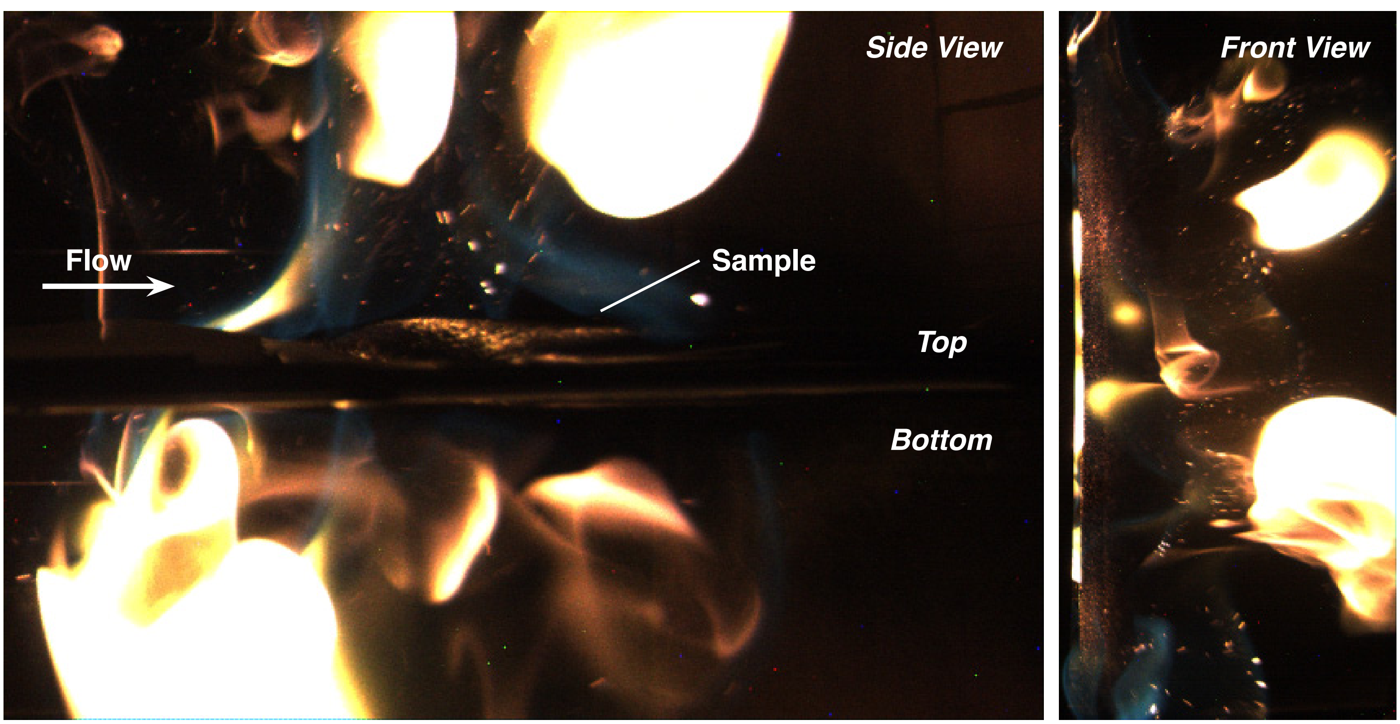
The NESC has initiated work on a new NASA valve standard that will address design, qualification, and environmental testing to set precise expectations and reduce the frequency of valve-related issues across NASA programs.

Prior to the launch of Artemis I, ground crew enter the mobile launcher and tightened several bolts to troubleshoot a valve used to replenish the SLS core stage with liquid hydrogen.

IN-PROGRESS:

Spacecraft Fire Safety Standard

The NESC is drafting a spacecraft fire safety standard to define a common approach to designing and verifying fire safety systems for spacecraft. The standard will address vehicle design, operation, material selection, fire detection, fire suppression, fire response, fire recovery, personal protection equipment, and crew training for fire events.



Side view (left) and top view (right) of an energetic fire in microgravity obtained during the Saffire-IV experiment (May 2020).

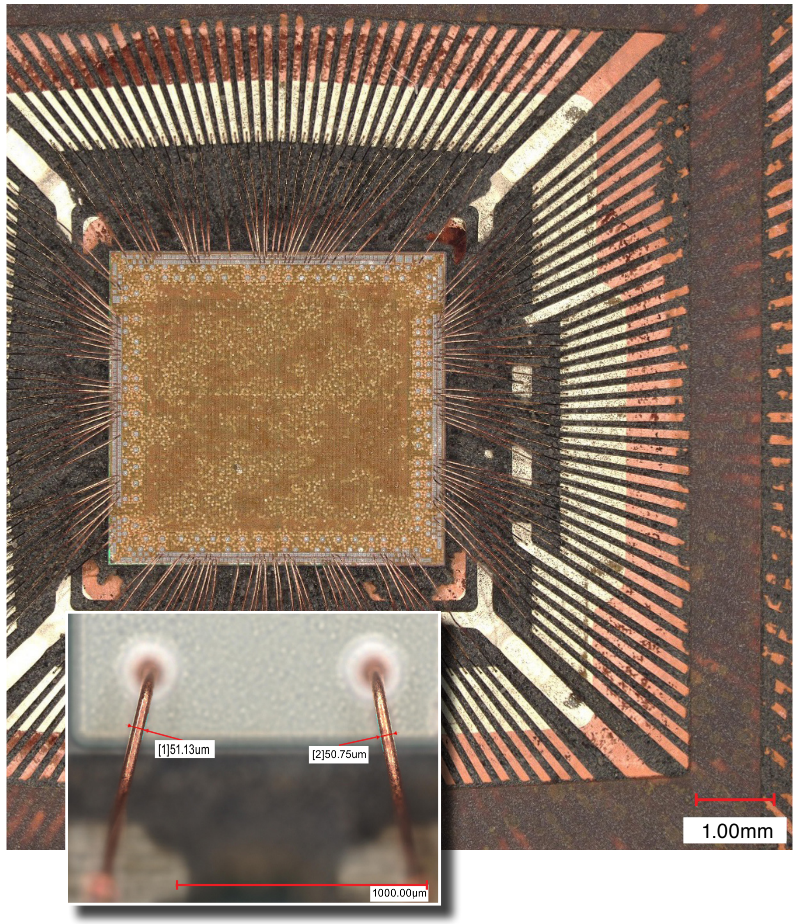
COMPLETED IN FY25:

Understanding Exposure and Environmental Stress on Copper Wire Bonds

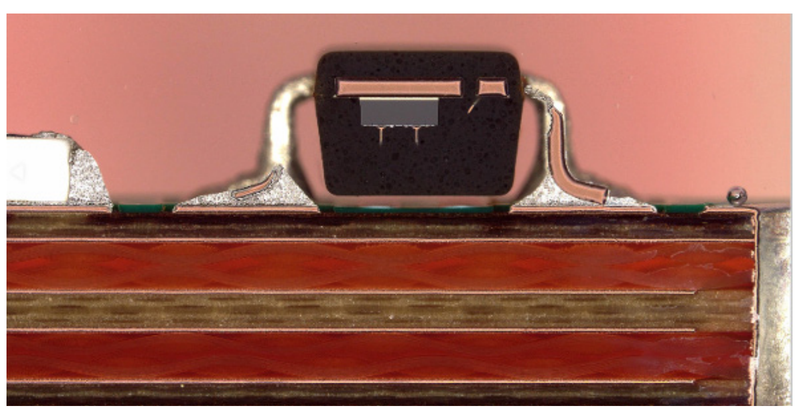
NASA is increasingly interested in using commercial off-the-shelf (COTS) parts, many of which use copper wire bonds. To ensure appropriate screening and qualification of these parts for space applications, the NESC performed an assessment focused on evaluating the risks and developing guidelines for using copper wire-bonded components. More recently, the NESC leveraged that work to test alternative methods for safely exposing (decapsulating) the wire bonds; study how environmental stress (like thermal cycling and high humidity under voltage) affects bond reliability; and start a NASA database of decapsulation images for future reference.

The team found ways to help optimize the decapsulation process and determined that copper wire bonds did not appear to degrade more quickly than surrounding elements such as solder joints. In addition, they created a public-facing database using cross-section images from the original NESC copper wire bond assessment and this follow-on work. The NESC provided data to the Defense Logistics Agency and industry to help add copper wire pull limits to MIL-STD-883, and provided decapsulation procedures to help enhance techniques through collaboration. The copper wire bond database can be found at https://nepp.nasa.gov/pages/cu_wirebond/.

This work was performed by Goddard and JPL.
NASA/TM-20230014536



Example of copper wire bonds.



A public-facing database was created using cross-section images from the original NESC Cu Wire Bond Assessment and this follow-on work.

COMPLETED IN FY25:

Cross-program Valve Anomaly Study

Following recent CCP valve anomalies, the NESC conducted a cross-program review of propulsion-system valve failures that focused not only on CCP but also across other NASA programs, like Apollo, Space Shuttle, and the Human Landing System. By looking for common threads among valve failures in these current and historical spaceflight programs, the NESC team hoped to find contributing factors and investigate potential mitigations.

The team focused on program design- and development-process histories to determine where standards were not followed, where gaps in standards might be present, and whether common threads existed across more recent valve failures, especially those pertaining to corrosive environments and propellant vapor exposure.

Following extensive reviews of program documents and related standards and investigation of contributing factors such as testing, materials, and environmental and exposure conditions, the team provided several recommendations regarding testing practices, design defects or unsuitability of materials, and controls for operations in environment/exposure conditions. While no specific valve standard existed at the time of this assessment, the NESC is currently developing a new valve standard under a separate assessment. This work was performed by Kennedy, Stennis, Marshall, Glenn, Johnson, and White Sands Test Facility.

During its valve study, the NESC looked at past and present NASA programs in its search for common threads among valve failures. This included the Space Shuttle. Pictured here, the Space Shuttle Discovery fires reaction control subsystem (RCS) thrusters as seen from inside the crew cabin.

IN-PROGRESS:
HFE Replacement and Qualification

Hydrofluoroether (HFE) organic solvents, like those used in thermal control systems on Orion and Gateway or for precision cleaning of hardware, are being phased out of production, and the NESC is identifying, testing, and qualifying potential replacement candidates and evaluating them for cleaning efficiency, flammability requirements, and materials compatibility.

Johnson's Precision Cleaning Lab is necessary for removing oil and grease from spaceflight and ground support equipment to prevent rust and corrosion.

COMPLETED IN FY25:
Estimating Risk When Reducing NDE

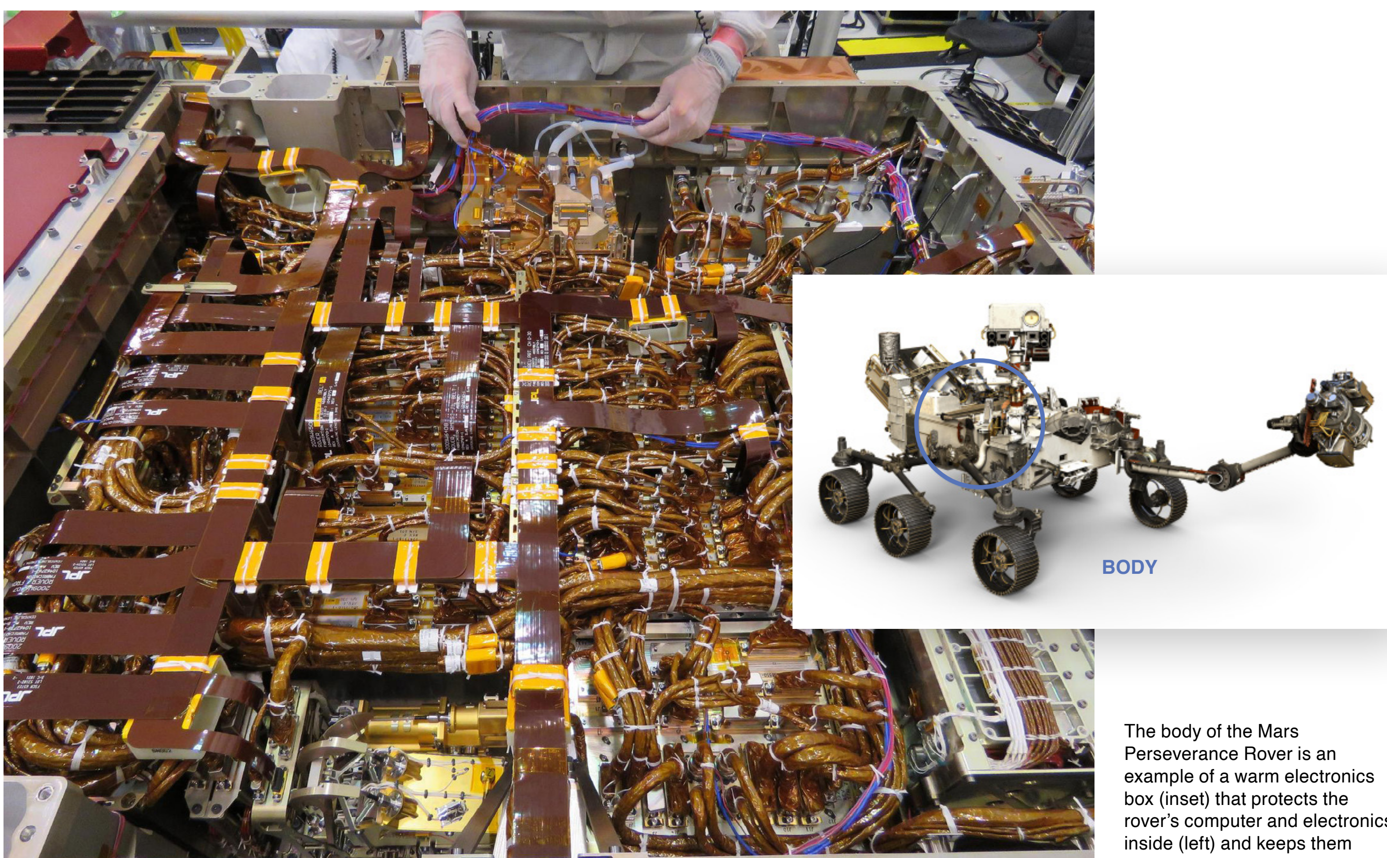
The NESC developed a methodology that can be applied by programs and projects to assess risk associated with nondestructive evaluation (NDE) descoping proposals. The NESC approach is applicable to a single NDE method for a wrought metallic part under measurable, monitored time-invariant process control. It conservatively assumes that a critical initial flaw size (CIFS) is equal to the NDE-detectable flaw size, and that if a CIFS defect exists, it will lead to structural failure. The methodology would be applied as part of a comprehensive review by the appropriate NASA Fracture Control Board or Technical Authority. For more information on this new methodology, see page 57. This work was performed by Langley, Kennedy, Johnson, Marshall, and Glenn. NASA/TM-20250004074

SPACE TECHNOLOGY
NESC TECHNICAL ACTIVITIES

COMPLETED IN FY25:
Cold-capable Electronics for Lunar Missions

For long-term crewed and robotic missions, NASA is going to need electronics that can operate in the lunar thermal environment where temperatures vary widely. Along the lunar equator, temperatures can range from more than 250°F in daylight to -208°F at night, with even colder temperatures in the permanently shaded regions. However, no established standards or recommendations exist to guide engineers and developers in qualifying electronic components for these applications. Though some electronics will be housed in a thermally controlled environment, like a lunar habitat or warm electronics box, having electronics that could withstand the lunar extremes without extensive thermal mitigation would be advantageous.

To bridge this knowledge gap, the NESC assessed existing cold-capable electronic and packaging technologies across NASA, industry, and academia, looking at best practices for selection and qualification as well as potential performance gaps. The work resulted in guidance and recommendations for developing and implementing these electronic systems for lunar missions. This work was performed by Goddard, Langley, JPL, and Glenn. NASA/TM-20250008583



The body of the Mars Perseverance Rover is an example of a warm electronics box (inset) that protects the rover's computer and electronics inside (left) and keeps them temperature-controlled.

AERONAUTICS
NESC TECHNICAL ACTIVITIES

IN-PROGRESS:
Updating Guidance on Flight Crew Alerting

The NESC is assisting the Federal Aviation Administration in updating its guidance for flight-crew alerting by reviewing data and identifying new human factors issues related to advances in automation. The activity will develop an overall alerting philosophy that draws on industry best practices, benefiting modern transport aircraft as well as NASA aeronautics and Moon-to-Mars programs.

IN-PROGRESS:
X-59 Fuel Tank Assessment

The NESC led, in partnership with Armstrong Flight Research Center, the design, testing, fabrication, and installation of an electronics box into the X-59 to mitigate risks associated with the flight strain gages. The NESC approach helped to maintain high-fidelity data acquisition, while eliminating a risk to flight operations.

NASA's X-59 quiet supersonic research aircraft lifts off for its first flight on October 28, 2025, from Palmdale, California.

ADDITIONAL IN-PROGRESS TECHNICAL ACTIVITIES

- Orion X Thrust Capability Study
- ISS Space to Ground Receiver Controller
- ISS Oxygen Generation Assembly
- ISS Firefly Aerospace Miranda Engine Performance
- Risk Using Cabin Depress for Fire Suppression
- SCAN DSS Antenna MIB Support
- Gateway High Gain Antenna RF Interference & Damage Analysis
- ISS NG-23 Delta Velocity Engine Anomaly Support
- CCP Parachute Degradation Statistical Support
- Gateway-HALO Corrosion Tiger Team
- CCP Evaluation of Probability of Detection Study
- Consulting for Swiftly Mission
- Performance Testing of Lithium-ion Batteries
- Dragonfly DraGMet Instrument Methane Sensor Support
- HLS Avionics CCF Vulnerability Assessment
- Orion CM Regulator Performance Issues
- TRACERS Post-launch Anomaly
- HLS Radiation Standards Evaluation
- Crewmember Contributions to Safety in Transport Aircraft
- PrK Mitigations
- CCP SPAM Cracks
- Carbon Plume Mapper M1 Support
- NASTRAN to LS-Dyna Best Practices Guide
- ORDEM4.0 Peer Review
- CLPS 1.0 Support
- Evaluation of GEO/NRHO Environment for Gateway GNC V&V
- CCP RCS Failure & Dropped Command Issue Support
- NESC Support for Controller Backplane Design
- Commercial Lunar Payload Services 2.0 Studies
- Orion CMHV Alternate Design
- X-59 Flight Computer Serial Comm Links
- Integrated Rotating Detonation Engine System Test
- GAO Commercial Services Test and Evaluation Best Practices
- M2M SE&I Artemis II Integrated Design Certification Review
- Reusability of R512E Coating and C103 in Propulsion Systems
- Model Crew Complement to the Surface of Mars
- Investigation of IM-2 (Athena) Landing
- Perfluoroelastomeric Compatibility with Nitrogen Tetroxide
- ISS USDV Technical Support
- COTS Parts Reliability Testing
- Oxygen Valve Failure Review Support
- Preventing Inadvertent Slide Deployments in Commercial Airline Operations
- Infineon MOSFET Radiation Susceptibility Cross-Program Impacts
- Graphic User Interface Standards and Crew Alerting
- Software MC/DC Testing of the USSF AFTS CASS
- Gateway and Power and Propulsion Element Propulsion Team
- Low Pressure Material Off-Gassing Characterization
- Europa Clipper Mission POGO Evaluation
- SMD Post-mission Disposal Support
- Temperature Measurement of Pc Strain Gauges
- Helium Seal Redesign
- Avionics/EME SME Support for JAXA HTV-X
- Gateway Computer-Based Control Systems Failure Tolerance
- Dragonfly Thermal and Computational Fluid Dynamics
- Low Mach, High Reynolds Number CFD Modeling
- Dragonfly Flight Dynamics Modeling
- Air Force HH-60W Static Charging
- HLS Elevator System Peer Review
- Electrostatic Discharge-Induced Ignition Risk in Suits
- NASA-STD-6001 Improvement Activities
- Textile Development for Oxygen Enriched Atmospheres
- JPSS-2 Anomaly Investigation and Spacecraft Charging Support
- ISS Water Separator Motor
- SIGMA Covariance Analysis Tool Development
- CCP Helium Leak Investigation
- Evaluation of Frangible Joint
- Lifetime and Capability Assessment of Inconel Heat Exchanger
- NASA-HDBK-5025 (Pyrotechnic Components)
- Broad ECLSS and EVA Support to ESDMD and SOMD
- C-103 Grain Size Sensitivity Testing
- Propagating Arcing Potential
- SLS Core Stage/EUS Thick Plate Short Transverse Ductility
- Energy Modulator Design-Iterations and Re-Qualification Testing
- Solar Energetic Electron Environments
- Agency Ignition Control Requirements
- Energy Modulator Box-Stitch Upgrade Testing
- Dragonfly Capsule Dynamic Stability Ballistic Range Testing
- Single Event Latch-up in Commercial Electronics: Risk Assessment/Mitigation
- HLS Flight Mechanics Abort/Failure Analyses Support
- Nuclear Electric Propulsion Technology Maturation Plan Non-Advocate Review
- Systems Engineering SME Support to Commercial LEO Development Program
- Damage Tolerance Testing for Axiom and Vivace
- Flight Deck Automation System Integration Assessment Transport Category
- Support to Sandia National Lab on Cooperative Agreement
- MPCV Explosive Transfer Line Assessment
- Mechanical Model Development and Parameter Selection for Propellant Slosh
- Ti-NTO Ignition Spots
- Uncertainty Quantification for Pressure Vessel Damage Tolerance
- Specifying Optical Surfaces to Control Near-Angle Scatter at <100 milli-arc
- Energy Modulator Extension Testing
- Programmable Logic Device Guidance and Standard
- Cracked Samples for NDE Standards
- Human System Interactions in Closed Breathing Systems
- Updates and Modernization of the CEA Code
- SLS Core Stage Thick Plate Issue
- Hot-Fire Testing of 5 lbf Class Reaction Control System Thrusters
- Study of Material Sensitivities to N2O4/MON Exposure
- Frangible Joint Working Group
- CCP Fracture Control Risk Reduction
- Gateway PPE COPV Damage Tolerance Life Support
- Frangible Joint Technical Support to SLS
- Thermophysical Properties of Liquid TEA-TEB
- MPCV COPV Damage Tolerance Life by Analysis Risk Assessment
- Fire Cartridge Failure Invest., Manufact., & Hardware Verific.
- Ti-NTO Compatibility Cross-Program Impact and Lessons Learned
- Tube Test Coupon for COPV Mechanics
- Issues with Qualification of Radiographic NDE Techniques
- BON GCR Model Improvements
- Material Compatibility and EAC Data for Metals in Hypergolic Propellants
- Solderless Interconnects and Interposers
- Hydrodynamics Support for the Orion CM Uprighting System
- CCP Parachute Flight/Ground Tests & Vendor Packing/Rigging Activities
- Southern Hemisphere Meteoroid Environment Measurements
- CPV Working Group
- Independent Modeling and Simulation for CCP EDL
- Reaction Wheel Performance for NASA Missions
- Exploration Systems Independent Modeling and Simulation
- Peer Review of the MPCV Aerodynamic/Aerothermal Database Models and Methods

ADDITIONAL TECHNICAL ACTIVITIES COMPLETED IN FY25

- Quick Review of Swift Boost Proposals
- SLS Autonomous Flight Termination Unit Preliminary Design Review
- High-Power NIR Optics and Windows
- Mortar Pyrotechnics
- Hubble Orbit Stability
- Crew Module Thruster Fail-Off Corrosion
- SLS Ascent Aerodynamic Stability Database
- HALO Motor Driver Shoot Thru Issue on Coolant Loop Pump Driver
- Hubble Orbit Decay Study
- M2M Program End-to-End Emulator Capability Development
- Artemis II Secondary Payload K-RADCube - Additive Manufacturing Review
- SME Support to ARB for Primer Coating Failure Affecting Multiple Projects
- Recertification of Silver-plated Copper Wire
- Peer Review of Proprietary Ablator Material
- CCP Propulsion System Risk Assessment
- MAV PDR Planning SE&I Support
- Support for PFE Selection
- ISS ACES Laser Support
- Dragonfly Parachute Decelerator System (PDS) Mortar Propellant Support
- CCP Paint Approval
- Orion Universal Waste Management System Sensor Failure
- Deep Dive Support of CCP Propulsion System
- SLS DP Measurement Oscillation Investigation
- HLS Cryo Fluid Management Cryocooler Risk Mitigation
- Lunar Terrain Vehicle Standards Evaluation
- Statistical Engineering Support for Gateway/HALO Thermal Coating System
- Artemis III Crew Module Hydrazine Crossover Valve Support
- Facility LN2 Dewar/Supply System SME Support for LaRC
- Nitrox Blow-Down Thermal Analysis
- STMD Cryo Fluid Management Road Mapping
- CLPS Payload Interface Logic and Definition
- Resolution of CCP Flight Anomalies
- Total Ionizing Dose Tolerance of Europa Clipper Power MOSFETs
- Lunar Landing Tip-over Hazard Cause Fishbone Exercise
- NDSB2 Passive Element Radiation and Internal Charging Review
- Libera Twist-Capsule Redesign Review
- ISS Deep Dive into CCP Software
- Failure-Tolerant Avionics for Crewed Space Systems
- Resolving Content Issues with NASA-HDBK-5023 (Frangible Joints)
- Balloon Program Quality Assurance Evaluation
- ESDMD Lunar Reference Frame Action
- Super Guppy Rescue Loader Hydraulics Support
- SMD ESCAPADE AM Ti Tanks Implementation Risks
- NISAR Reflector Thermal Issue
- Goddard Large Vibration Test Facility Anomaly
- Nova-C Lander Propulsion Schematic Review
- Ames Arc Jet Complex Modernization
- Flight Projects Mission Critical Telemetry/Commanding Availability
- EGS ML1 Heritage Cryo Piping Assessment
- JSC Mission Control Center Backup Electrical Power
- 20K Cryocooler Anomaly Support
- HLS/Gateway Docking Loads Due to Low-Gravity Propellant Motion
- Smart Initiator DLAT Wire bond Failure at Low Temp
- Updated Reliability Evaluation of MPCV SM Fairing Panel FJ for Artemis II+
- HLS Guidance Algorithm Evaluation
- Psyche Cold Gas Thruster Technical Advisory Team Support
- Moon-to-Mars Artemis II Critical Event Review
- SLS Debris Resolution Team (IRT)
- SX50 Pressure Sensor Anomaly
- ISS PrK Structural Atmospheric Leak
- Mass Properties Evaluation of CCP Providers
- Cryogenic Fluid Management Support to DARPA Project
- Spacesuit Material Wire Ignition Risk Mitigation
- PFE Microgravity Compatibility Test
- SpaceVPX Interoperability Open Standard
- CO2 Removal Expertise for JAXA I-Hab
- Systems Engineering and MBSE Support to Advanced Capabilities Division
- Orion Crew Module Heat Shield Avcoat Char Investigation
- DaVinci Mission Technical Support
- Artemis I Orion PCDU Latching Current Limiter
- Pyro Cable Analysis
- Lunar Suit Tribocharging Risk
- Friction Stir Welding Support
- Display Management Computer (DMC) Reset Anomaly
- Composite Consult for New Launch Vehicle Application
- Hardline O2 and Fire Response
- EMU Water Management
- Capsule Dynamic Pitch Testing at Transonic Speeds
- SubC Safety Review
- Power and Propulsion Element Battery Safety
- Dragonfly Dynamic Stability
- Oxidizer Tank Design and Qualification Assessment
- AACT Risk Reduction Project – in Situ Monitoring Category
- AACT Risk Reduction Project - Metallurgy Category
- Frangible Joint Technical Support to LSP
- Mars Sample Return MMOD Protection Review
- Test and Modeling to Predict Spacesuit Water Membrane Evaporator Failures
- MAV Buffet / Aeroacoustics Numerical Simulations
- Evaluation of Alternate Helium Pressure Control Component
- Orion Titanium Hydrazine Tank Weld
- SLS Aerosciences Independent Consultation and Review

NESC AT THE CENTERS

MEET ENGINEERS AND SCIENTISTS WHO LEND THEIR EXPERTISE TO NESC ACTIVITIES.

Drawing on resources from across the agency ensures that any technical challenge the NESC has been asked to address has the right team to solve it—not only the right expertise but the unique perspective that each center employee brings to the problem.

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928 EMPLOYEES supported NESC work in FY25 from across all NASA centers.

AMES RESEARCH CENTER

108 AMES EMPLOYEES SUPPORTED NESC WORK IN FY25

The Ames Research Center provides a combination of unique engineering personnel, testing facilities, and computational resources to the NESC. Over the past year, several of the NESC's technical assessments have depended on Ames's world-class arc jet; advanced supercomputing; electrical, electronic, and electromechanical (EEE) parts; and space biology facilities/expertise to formulate the recommendations the NESC made to the agency regarding active human and robotic spaceflight missions. Ames personnel were active members of 19 of 20 NESC TDTs, and the Technical Fellows for Aerosciences and Human Factors both reside at Ames. Other center staff supported many NESC technical activities including those for Dragonfly dynamic stability, Crew Exploration Vehicle aerosciences peer review, Sabatier protection technology, commercial-off-the-shelf parts screening and selection, and the Orion crew module heat shield Avocat char investigation. This year's profiled individuals participated directly in these activities and demonstrate the diversity of expertise present at Ames.

DR. DONALD R. MENDOZA
NESC CHIEF ENGINEER

Grace Belancik

At age 11, Ms. Grace Belancik attended Space Camp in Huntsville, Alabama, and was immediately hooked. "At that point I decided that I was going to do everything in my power to figure out how to work for NASA," said Belancik. And she did. Majoring in chemical engineering, she secured her spot and is now the Air Revitalization Team Lead at Ames.

Her work focuses on environmental control and life support (ECLS) systems. "We mainly focus on CO_2 removal. We all exhale a kilogram of CO_2 per day, and when you are in enclosed environments, you can quickly run into problems if you don't get rid of that CO_2." Her team is developing new technologies for highly reliable and regenerative methods of scrubbing CO_2. "The technologies we've used on ISS are great, but if we go to Mars, we won't be able to replace anything for five years, so is there a better way to do it? That's what I'm investigating."

With 16 years of NASA experience, her knowledge has been invaluable to the NESC ECLS Technical Discipline Team (TDT) and NESC assessments, most recently with a review of the Boeing Starliner Environmental Control Active Thermal Control System. "The assessments let me participate in things that are in my field but that I would not normally see in my day-to-day work. And the TDT is a great way to see the ECLS big picture and how everything interacts and integrates. I enjoy applying my skills to all those different areas."

Kuok Ling

As the use of commercial-off-the-shelf (COTS) EEE parts spreads across NASA programs, Mr. Kuok Ling's breadth of knowledge in this area has been invaluable to NESC assessments and to the Avionics TDT. "I was designing chips in the semiconductor industry for almost 20 years," said Ling of his work prior to joining NASA Ames 18 years ago as an electrical engineer.

Having worked in nearly every aspect of chip manufacturing, he leveraged that experience to help Ames develop its COTS use policies and has helped educate the broader NASA community on the benefits of COTS parts use in missions. He also assisted in an NESC assessment to develop appropriate guidance for the test, screening, qualification, and reliable use of COTS and new EEE parts technologies at the agency.

"We developed a concept called Industry-Leading Parts Manufacturer," he said, "where we develop good relationships with manufacturers, fully vet their parts, and add them to our EPARTS database for NASA-wide use. It's been really great."

As part of the Avionics TDT, he meets regularly with his counterparts at other centers to collaborate on advancing the discipline. "I think that's what we should be doing more, and why I'm more than willing to share what I've learned with the rest of the agency."

ARMSTRONG FLIGHT RESEARCH CENTER

29 ARMSTRONG EMPLOYEES SUPPORTED NESC WORK IN FY25

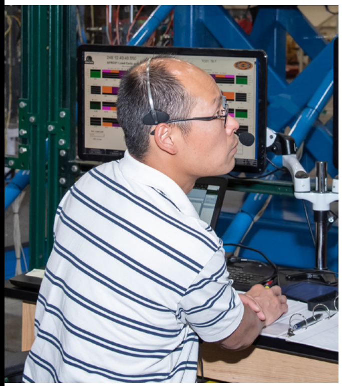
This year the Armstrong engineering workforce supported the agency-wide NESC technical discipline teams and several NESC assessment and support activities for both aircraft and spacecraft. The Armstrong team conducted research systems development and flight-test activities supporting NASA's missions and operated over 1,150 flights on NASA research and support aircraft. NASA's Quesst Quiet SuperSonic Technology mission made great advances at Armstrong including demonstration of in-flight shockwave imaging, ground detection, recording, and reconstruction of shockwaves, and the final assembly and testing of critical subsystems on the X-59 Low-Boom Flight Demonstrator Aircraft in preparation for the first flight and the beginning of three phases of flight testing. The NESC also participated in a flight test campaign to study and improve high performance aircraft life support systems at Edwards Air Force Base.

SEAN CLARKE
NESC CHIEF ENGINEER

Jessica De la Cruz

Aerospace engineer Ms. Jennifer De la Cruz specializes in combined thermal and vibration loads testing, processing vibration data for multiple aircraft like the F-15, F/A-18, and Global Hawk. She is also involved in projects through the Armstrong Center Innovation Fund (CIF) Program, which allows engineers to explore new concepts that could lead to advancements in aeronautics and space exploration. For the last two years, she has presented her thermal vibration test system CIF project's progress at the NESC's annual Structures, Loads & Dynamics, Materials, and Mechanical Systems workshop.

"I got a lot of important feedback from NESC experts that was really helpful, not only for my professional development but also for the project. I also networked with other early careers from across the agency. It was very exciting," she said. "And definitely an opportunity to grow as an early career."



Wesley Li

An 18-year veteran of Armstrong, Mr. Wesley Li specializes in structural analysis including loads, dynamics, and aeroelasticity. His primary role at Armstrong is ensuring the structural airworthiness of Armstrong's flight-test aircraft and test articles. Having collaborated in an NESC assessment of the X-57's mechanical design, he has since joined the Structures Technical Discipline Team (TDT), where he lends his expertise in assessing structural concerns and providing technical input on structural aspects. "The NESC project provided valuable opportunities to collaborate with the TDT members and benefit from their expertise. As a new member, I am gaining deeper insight into the issues the TDT is addressing in my discipline," he said. "I also enjoy contributing the AFRC perspective and experience in aircraft. Interacting with and learning from the NESC's exceptional engineers has been an incredible experience, and I am proud to be part of this distinguished group."

Cryss Punteney

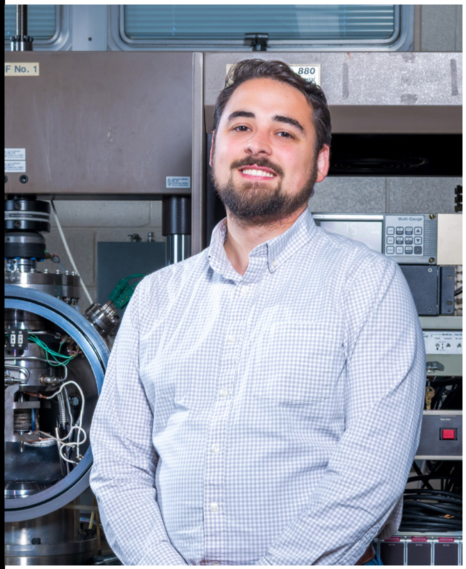
As an environmental test technician, Ms. Cryss Punteney supports the engineering branch at Armstrong. "I do environmental testing, which includes altitude and temperature testing for all the components that go on our aircraft," she said, "as well as shock and vibration testing to ensure the components can sustain the conditions of flight." Recently her work included assisting the NESC with testing of excitation fault protector boards in support of an X-59 assessment. "We did both the altitude and temperature testing in one of our chambers, and then put the boards on the vibe table to ensure that they were able to survive in the X-59." Punteney built, stacked, and mounted test fixtures on the vibration table to test the boards. "We shook them for quite a long time." Punteney loves "being a part of every single project that we have here," and the variety of customers she supports, from NASA, the military, and organizations like the NESC. "Whatever we're building and putting on our aircraft has to be tested in my lab before it goes on the aircraft."

GLENN RESEARCH CENTER

63 GLENN EMPLOYEES SUPPORTED NESC WORK IN FY25

The Glenn Research Center provided a broad spectrum of technical expertise to 24 NESC technical assessments/activities and 18 NESC TDTs. These activities supported all NASA mission directorates and several cross-cutting discipline efforts. Significant Glenn contributions this year were in support of understanding the Niobium alloy, C103, and how it performs under extreme conditions. The NASA Technical Fellows for Cryogenics and Loads & Dynamics and deputies for the Cryogenics, Electrical Power, Materials, Thermal Control & Protection, Propulsion, Nuclear Power & Propulsion, and Software TDTs are resident at Glenn.

ROBERT S. JANKOVSKY
NESC CHIEF ENGINEER



Dr. Chris Kantzos

As a materials research engineer, Dr. Christopher Kantzos helps develop new materials and bring others to maturity, but much of his time is spent testing existing materials to ensure they are safe for use in the harsh environments of space. Currently, he is assisting the NESC with testing of a niobium-based alloy called C103. "We lack data on its performance at extreme temperatures, so we are machining test specimens, inducing cracks, and testing them to observe crack growth. Then we provide that crucial data to program engineers so they can understand how cracks grow in their hardware and the potential for component failure." he said.

Kantzos said Glenn has the unique capability to conduct high-temperature and vacuum tests for components operating in space. He collaborates with test engineers, handles specimen design and testing parameters, and performs the post-test data analysis. “This process is common for new materials that are aiming to outperform existing ones at specific temperatures,” he said. He enjoys the unique challenges the work brings, such as achieving consistent heating in a vacuum chamber and analyzing complex and statistical crack-growth data. He also takes advantage of the close proximity of Glenn to the Metroparks that run from Lake Erie through Cleveland. “Outside of work I spend a lot of time in the park exercising, playing basketball, and enjoying a new hobby, photography.”

Dr. Elizabeth Young-Dohe

Since Dr. Elizabeth Young-Dohe joined NASA in 2019, she has spent much of her time working with the NESC, using her years of materials expertise to help to investigate a spectrum of anomalies in engines, hardware, and structures. Her industry knowledge of ceramics and high-temperature coatings along with research in a wide variety of materials such as refractory metals and regolith concrete has sustained her interest in materials characterization and failure analysis.

An experienced user of scanning electron microscopy (SEM), she views the technology as “a way to use my skills to make a picture worth 1000 words. I learned SEM when I was an undergraduate, and then taught the laboratory section of the class during my Ph.D. I try to image samples in ways that make words unnecessary,” she said. “The work that goes into a picture is the secret, working with a material to prepare it for the microscope educates me more about the material than just reading about it.”

For Young-Dohe, NESC investigations are always interesting. “Failure analysis is like a puzzle, and putting all the evidence together to create a picture of what happened is an enlightening experience.” The challenge, she added, is “making sure to capture all the evidence before it is destroyed through handling or an additional test method.”

GODDARD SPACE FLIGHT CENTER

80 GODDARD EMPLOYEES SUPPORTED NESC WORK IN FY25

The Goddard Space Flight Center supported a wide range of NESC work including 62 activities and 17 TDTs with 80 engineers, technicians, and scientists participating. Goddard supported the development of programmable logic device guidance and standards, provided leadership in identifying electronic parts and packaging industry-leading parts manufacturers for NASA, evaluated the new backplane design for the SpaceX-proposed F9 second stage Falcon controller, and supported investigations for the Orion Universal Waste Management System sensor failure. Contributions to the Science Mission Directorate included impact analysis of shorter post-mission disposal times, the Hubble Space Telescope expected orbit decay, DaVinci aeroacoustics, Commercial Lunar Payload Services payload interface logic, and the Balloon Program quality assurance. The NASA Technical Fellows for Systems Engineering, Avionics, and Mechanical Systems as well as the NESC Integration Office liaison for SMD, STMD, and ARMD reside at Goddard.

CARMEL A. CONATY
NESC CHIEF ENGINEER

Lyudmyla Panashchenko Ochs

Since arriving at Goddard 15 years ago, Ms. Lyudmyla Panashchenko Ochs has been assisting the NESC in failure analyses, typically of electronic parts like resistors, capacitors, or microcircuits, which is her specialty at the center. Her work is key to ensuring Goddard science instruments can operate reliably for long-duration missions. “I'm the person who helps figure out what led to the failure,” she said. “We do extensive ground testing—temperature cycling, vibration, and letting the instrument run for a long time. If it's experiencing a hiccup, we can troubleshoot and find any anomalies early before the parts get into space.”

Her investigations for the NESC have included the Hubble Space Telescope and ISS. Most recently, she and her team analyzed a capacitor used on both the ISS Universal Waste Management System and throughout the Artemis campaign, demonstrating the cause of on-orbit failure and running remaining parts through accelerated testing to determine any propensities for future failure. She and her team also tested copper wire bonds inside plastic microcircuits to demonstrate their long-term reliability. “I really enjoy working with NESC,” said Ochs, “With their technical expertise, they quickly jump into a problem to see how they can help. And they don't bring egos in. They listen, which makes the process go faster and makes for a very pleasant work environment.”

Jonathan Boblitt

Mr. Jonathan Boblitt is wrapping up his work as the technical lead for the NESC’s development of a programmable logic devices (PLD) standard. These electronic components, used to build reconfigurable digital circuits, are user-programmed to perform specific logic functions and are found in a wide range of avionics. To develop a comprehensive set of proposed best-practice requirements, the NESC team synthesized and collated requirements, procedures, and guidelines from both NASA and industry PLD practices.

“‘Are FPGAs software or hardware?’ is a contentious, more than 16-year-old, NASA conversation. We haven’t had a standardized approach to PLD development across NASA,” said Boblitt, a computer engineer with expertise in field programmable gate arrays (FPGA), a type of PLD. This means NASA projects and programs have tended to develop unique PLD practices for their applications. “These requirements will ensure a consistent, quality product, with appropriate visibility, documentation, assurance, and verification practices.” When the work is done, Boblitt intends to build on that effort by enabling a NASA-wide repository of FPGA cores and accelerating FPGA design with generative artificial intelligence. “Every FPGA team has its own repository, and we are duplicating efforts. If we can create a NASA-wide catalog of available FPGA cores, that would be fantastic,” he said. “I know that would make my job a lot easier.

JET PROPULSION LABORATORY

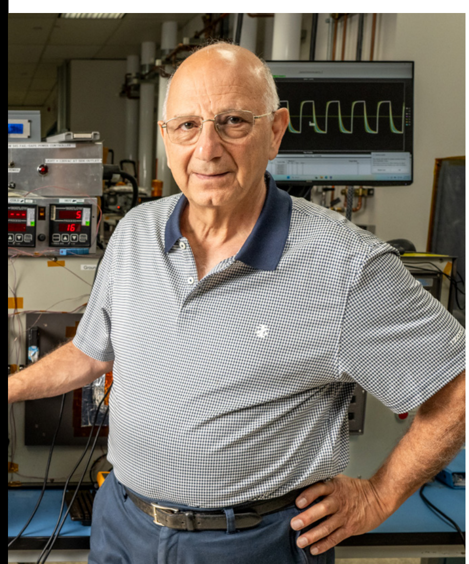
80 JPL EMPLOYEES SUPPORTED NESC WORK IN FY25

The Jet Propulsion Laboratory (JPL) provided technical leadership and engineering expertise to more than 30 new or ongoing NESC assessments and 19 Technical Discipline Teams (TDT) in 2025. JPL's expertise in composite overwrapped pressure vessels (COPV), entry, descent and landing (EDL), avionics, environmental monitoring, additive manufacturing, mechanical structures and thermal analysis supported assessments for a variety of programs and projects within NASA's Mission Directorates. Significant contributions included analysis of cold electronics for lunar missions, thermal testing in support of lunar glove analysis, development of standards for NASA's next generation spacecraft avionics, updates to the NASA valve standard, as well as guidance, navigation and control, flight mechanics, and EDL expertise in support of the Commercial Crew Program. More than 50 JPL employees served on TDTs, working with NASA Technical Fellows on advancement of agency engineering initiatives. JPL provided leadership for the COPV Working Group, and the TDT deputies for Space Environments, Electrical Power, Mechanical Systems, and Loads and Dynamics reside at JPL.

KIMBERLY A. SIMPSON
NESC CHIEF ENGINEER

Dr. Marcus Lobbia

Dr. Marcus Lobbia, a seasoned expert in entry, descent, and landing (EDL) systems, was brought into an NESC assessment last year to lead updates to NASA's independent verification and validation (IV&V) EDL trajectory simulation for a commercial provider. At JPL, he coordinates EDL systems engineering for Mars missions, working on aerodynamics, aerothermal, and trajectory analysis, and more. However, this was Lobbia's first opportunity to interact with NASA's Commercial Crew Program (CCP). Despite his initial unfamiliarity with CCP and the software tool used to create the simulation, Lobbia leveraged his more than 20 years of experience as well as the invaluable assistance of the NASA CCP IV&V team to support the updates, aimed at ensuring the safe reentry and active deorbit and burn-up of a jettisoned portion of the spacecraft over the Pacific Ocean. "It was a complex simulation, so there were quite a few changes that had to be made to flight software and configuration files," he said. He also honed his skills with the software tool and ultimately assisted in the CCP IV&V team taking ownership of the simulation. Lobbia is also a member of the NESC's Aerosciences TDT, contributing his expertise in computational fluid dynamics, aerodynamics, and thermal protection systems. "The technical capabilities of the NESC were the highest level. And the team didn't care what center everyone was from, as long as you had the technical expertise to do the job and could work together to get it done."



Dr. Mohammad Mojarradi

Dr. Mohammad Mojarradi recently lent his expertise to an NESC assessment focused on developing guidelines for electronics that can operate in the Moon's extreme thermal environment. With temperatures ranging from -330°F to +250°F on the surface--and dipping as low as -400°F in permanently shadowed regions—lunar conditions far exceed the design limits of typical commercial or military-grade electronics. "The Moon's temperatures are unlike anything terrestrial systems are built to handle," he noted. As part of the assessment team, Dr. Mojarradi contributed his specialized knowledge in integrated circuit design, joining experts from across NASA in electronics development. The effort involved a detailed study phase, drafting, and rigorous peer reviews by both internal and external stakeholders. "We've now completed the final report, which has been reviewed and is ready for release," he shared. Since joining NASA in 1998, Dr. Mojarradi has been deeply committed to pushing the boundaries of extreme-environment electronics. "This project was a dream come true for me," he said. "Cold electronics that perform reliably in cryogenic conditions enable more of a spacecraft's power to be used for science instead of heating—something that could make a real difference." He also underscored the broader mission: "NASA is recognized worldwide for our bold discoveries and missions. Continuing this kind of pioneering work is essential to maintaining that legacy."

JOHNSON SPACE CENTER

148 JOHNSON EMPLOYEES SUPPORTED NESC WORK IN FY25

In 2025, Johnson Space Center and White Sands Test Facility personnel provided expertise to 83 active NESC technical activities with 148 engineers supporting 17 NESC TDTs. The NESC continues their partnership with the Johnson Engineering Directorate to prepare Orion for the Artemis II mission as well as collaborating with Johnson Center Operations to resolve ongoing electrical challenges with systems supporting critical Mission Control Center systems. Multidiscipline teams are investigating material flammability in different oxygen content environments to aid programs in understanding ignition source risks. Engineering teams completed their investigation of the ISS Russian Segment PrK cracks with results informing programmatic risk discussions and future operations. Engineers are collaborating with ISS, the Sierra Space Dream Chaser team, and the United States De-Orbit Vehicle team in addressing propulsion testing approaches and continue their analysis and test support of the Gateway Program in understanding battery and thruster performance.

JOEL W. SILLS
NESC CHIEF ENGINEER

Dr. Emily Hacopian

Using higher oxygen concentrations in Human Landing System crew cabins can shorten a crew's staging process for extravehicular activities, allowing more time on the Moon's surface. But NASA needs to ensure today's commercial materials will not be a flammability risk. "We haven't operated at these concentrations since Apollo," said Dr. Emily Hacopian, a flammability expert in the Materials and Processes Group at Johnson. She is developing test programs, including building mini-mockups of crew cabins, to understand how fire spreads in those atmospheres and is working with the NESC to conduct flammability testing on a variety of materials. "There's this inherent randomness to flammability that I think keeps it interesting. You might predict a certain outcome, but it doesn't always turn out the way you expect. Luckily, it's unpredictable in the lab environment, so that by the time it gets to the spacecraft, we can adequately predict what to expect."

Dr. Tom Leimkuehler

Dr. Tom Leimkuehler's childhood dream of becoming an astronaut didn't work out, but he said working at Johnson got him pretty close. A perk of mentoring Johnson flight-program students was accompanying them on NASA's aircraft used to simulate weightlessness. And back on Earth, his thermal systems expertise keeps NASA's missions flying. For the last 5 years he has worked with the NESC, serving on the Thermal Control & Protection Technical Discipline Team (TDT) and supporting NESC assessments, like the phase-out of a coolant used in spacecraft like Orion and Gateway.

"We need to figure out what alternative fluids we will use in future vehicles," he said of his work to understand the thermophysical properties of replacement candidates. He is also helping the Dragonfly mission with their unique thermal challenges. "I enjoy working with the best of the best from inside and outside the agency," he said, a perk of working with the NESC.

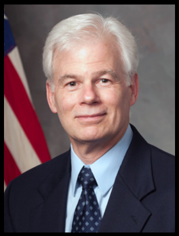
Justin McFatter

After 19 years at The Boeing Company, where he worked with ISS and the NASA Docking System, Mr. Justin McFatter joined NASA in 2022, where his experience aids in modeling and simulation of mechanical and fluid systems, including electromechanical, hydraulic, and pneumatic actuators; control systems; and contact mechanics. He also supports the NESC as a member of the Loads & Dynamics TDT and has worked on assessments where he modeled propellant slosh during on-orbit docking and helped improve a model's fidelity for the Orion side hatch. "NESC independent assessments can uncover perspectives a program may not have considered, and give me an opportunity to explore new ways of approaching problems," he said. "I've learned a lot through interacting with NESC experts who have a wealth of experience and differing backgrounds. It's an invaluable growth opportunity."

KENNEDY SPACE CENTER

47 KENNEDY EMPLOYEES SUPPORTED NESC WORK IN FY25

Kennedy Space Center personnel provided technical expertise to 40 NESC activities and TDTs in 2025. They engaged in numerous NESC assessments including agency-wide testing for cleaning solvent replacement, Commercial Crew Program (CCP) thruster pressure transducer troubleshooting, and a parachute design guideline document. Likewise, the NESC supported several Kennedy CCP activities, including portable fire extinguisher microgravity compatibility testing, thruster corrosion and coating reusability analysis, thruster helium seal analysis and testing, and independent modeling and simulation for entry, descent, and landing. The NESC also invested in Kennedy's Applied Physics Lab to perform thruster pressure transducer anomaly testing and Investigative Chemistry Lab for agency solvent compatibility testing.



STEPHEN A. MINUTE
NESC CHIEF ENGINEER
(Retired 2025)

GREGORY T. HORVATH
NESC PRINCIPAL INTEGRATION ENGINEER

Brandon Marsell

As Chief of the Environments and Launch Approval Branch for the Launch Services Program, Mr. Brandon Marsell and his team collaborate with commercial providers to integrate NASA spacecraft onto commercial rockets. They oversee thermal analysis, venting, external aerodynamics, and electromagnetic interference to ensure safe and successful missions. He also serves as the Deputy for the Cryogenics TDT, where his expertise has been invaluable to NESC assessments.

When a commercial provider experienced an anomaly with a composite overwrapped pressure vessel, Marsell assisted in the investigation, traveling to White Sands Test Facility and setting up a test rig to simulate pressure vessel loading. The data collected helped inform models and recommendations for corrective actions. “This was a significant effort and one of my favorite NESC projects,” said Marsell. Recently, he hosted the Cryogenics TDT annual meeting where experts meet to discuss the future of the discipline. “One of our biggest challenges is managing cryogenic propellants for extended missions to the Moon or Mars. The technology needed doesn't exist today, making it a significant challenge to develop and implement,” he said. “That is what I like about the NESC. They reach across centers and industry, providing a true source of subject matter experts that can help with any problem. Leading cryogenics technology through its development and growth is gratifying, particularly knowing you are shepherding an entire discipline.”

Stefan Tomović

As an electronics engineer, Mr. Stefan Tomović works in Kennedy's Prototype Development Lab designing custom electronics, assembling test setups, and building data acquisition systems. Initially working on flight projects, he recently transitioned to NASA Solves, a problem-solving team overseen by Dr. Robert Youngquist, Dr. Christopher Biagi, and Dr. Doug Willard. "They formed this team to help train the next generation, so most are early career like me,” said Tomović. “It's a great vehicle for transferring knowledge.”

He recently assisted in an NESC assessment to research and find the cause of an anomaly with a vendor’s pressure sensor. "I led the design and helped execute the test, replicating the in-flight anomaly on the ground and building custom diaphragms for sensors used in testing.” He also worked with Dr. Biagi to develop a new method using joule heating for faster sensor testing. "The method shrinks the time scale, giving us a closer 1-to-1 of what you'd see in flight."

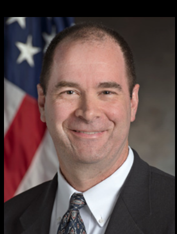
Tomović enjoys the hands-on nature of his work. "You learn a lot faster by doing things versus just watching," he said. And the dynamic nature of NESC projects keeps him engaged. "You learn really fast and provide results quickly. You're continually facing new challenges within your discipline, and you continue to learn. That's what makes it really exciting."

LANGLEY RESEARCH CENTER

200 LANGLEY EMPLOYEES SUPPORTED NESC WORK IN FY25

More than 200 people from Langley Research Center supported 59 NESC technical assessments and support activities during FY25, with 23 of those teams led by Langley personnel. The center contributed expertise and facilities to some of the NESC's important activities including those that addressed Russian ISS PrK module leakage, Orion crew module heat shield damage, Artemis II service module fairing panel separation reliability, Gateway computer-based control systems failure tolerance, and parachute energy modulator design and qualification. The NASA Technical Fellow for Sensors and Instrumentation resides at Langley along with seven TDT deputies and 119 TDT members from across 13 of the 20 TDTs. Langley also hosts the NESC Director and the Management and Technical Support offices.

K. ELLIOTT CRAMER
NESC CHIEF ENGINEER
(Retired 2025)



MICHAEL D. SQUIRE
ACTING NESC CHIEF ENGINEER

Stephen Cutright

As a structural dynamics engineer, Mr. Stephen Cutright has spent more than 16 years assessing the impacts of acoustics and vibrations on the structural response of flight components. From satellites and launch vehicles to fixed wing and vertical takeoff aircraft, Cutright has an extensive background in testing hardware to ensure it's ready for the demands of the flight environment. His recent work with the NESC, however, took him down a new path—testing parachute energy modulators (EM), which are designed to reduce the impulse, or "snatch loads," on various parachute system components during their energetic deployment. "At that time, I knew very little about parachute systems and the textiles that go with them," he said. But he did know about developing test plans, operating parameters, and procedures; designing and analyzing test support hardware; and overseeing test logistics and test-day activities. He learned all about EMs along the way. "It's been a great experience working with the NESC. They have tough technical challenges that require immediate solutions, so you really have to have a wide understanding of the different engineering disciplines." Testing EMs on the ground was particularly challenging, Cutright added. "It's typically done through drop tests or flight tests, but we were able to get a lot more information by using high-speed video, attaching load cells to all the EMs, and then swinging a large, heavy swing mass from the gantry to deploy these modulators. That's definitely thinking outside of the box."

Dr. Paul Leser

Dr. Paul Leser has provided his crack growth and failure analysis expertise to the NESC many times over the last several years. Most recently he has served as the primary analyst for the NESC's assessment of the ongoing leak in the ISS Russian segment (PrK), developing test methods and simulations to evaluate its remaining life and manage the risk of potential failure. Leser describes the work as particularly unique. "Typically, my work involves analysis after something has already failed. With PrK, we're watching this structure reach the end of its service life in real time. It's been very different than most of the other assessments I've worked." But Leser enjoys the challenge. "NESC assessments are always interesting problems, first and foremost. Almost by definition, they are usually urgent and important to the agency mission. And the NESC has some of the smartest engineers we've got in the agency. So, it's been a great learning experience working with them."

His initial involvement with the NESC was thanks in part to location. "When I joined NASA and the Damage Tolerance and Reliability Branch at Langley 13 years ago, the Materials Technical Fellow at that time was sitting in my branch. I had the opportunity to meet him, and he got me involved on my first assessment. I'm really appreciative of them for giving me that first shot, and it's really defined how my career here has gone so far."

MARSHALL SPACE FLIGHT CENTER

153 MARSHALL EMPLOYEES SUPPORTED NESC WORK IN FY25

Marshall Space Flight Center continues to provide exceptional engineer, scientist, and technician subject matter expert support to 38 NESC technical activities involving exploration systems development, space operations and environmental effects, science, and crosscutting discipline activities. The NASA Technical Fellows for Propulsion, Space Environments, Environmental Control & Life Support, and Flight Mechanics, and the TDT Deputies for Propulsion, Nuclear Power and Propulsion, Materials, Space Environments, Structures, Sensors & Instrumentation, and Software are resident at Marshall.

STEVEN J. GENTZ
NESC CHIEF ENGINEER
(Retired 2025)

ANDREW C. CHALOUPKA
ACTING NESC CHIEF ENGINEER

Dr. Anthony DeStefano

Dr. Anthony DeStefano, a space environments engineer with the Natural Environments Branch, developed a new lunar meteoroid ejecta model that will help inform the design of Artemis mission elements like the Human Landing System. "Ejecta plume from a meteoroid hit could pose a risk to lunar landers or astronauts," said DeStefano, and his new model incorporates what NASA has learned about the lunar environment since the Apollo era. Though having served as a member of the Space Environments Technical Discipline Team and as a consultant on an NESC assessment for spacecraft shielding radiation dosage, DeStefano was on the other side of the assessment when he asked the NESC to review his ejecta model. “That was a good learning experience too,” he said. “They can gather the right experts to bring in different perspectives that can help you discover holes in your thinking or find a different approach to the problem.”

Mike McCormick

In their day-to-day support of the ISS, Mr. Mike McCormick and his team are responsible for continuous upgrades and troubleshooting any anomalies that may arise. As a senior mechanical engineer, he has dedicated more than 25 years to Environmental Control and Life Support Systems (ECLSS), working with flight hardware design, development, and testing. That experience has been vital to the NESC, most recently with a wire bundle air flow assessment. “Our support involved the development and build-up of a test stand to measure the delta pressure across a cylindrical bed packed with wire bundles at various packing percentages. The packed bed was exposed to controlled airflows with the monitoring of the packed bed delta pressure and other environmental inputs,” he said. He enjoyed the opportunity to work with the NESC ECLSS team. “It's incredibly rewarding to see our efforts contribute to the success of the ISS."

Michaela Tarpley

As a navigation engineer with Amentum Space Exploration Division in Marshall’s EV42 branch, Ms. Michaela Tarpley works on the Human Landing System project, updating and enhancing navigation simulation models. Recently, she joined an NESC team working on Swift Integrated Guidance, Navigation, and Control and Mission Analysis (SIGMA) software (formerly LinCov) to make it widely available to all who need it. “I was interested in doing linear covariance analysis,” said Tarpley “It is tangential to navigation work, but it expands to model all the subsystems of a spacecraft.” As an early-career engineer, Tarpley was excited for the opportunity. “I just started at NASA last year, so it's been great to meet new people across centers and talk with experts in this type of analysis. I feel like I've learned a lot just by sitting in the discussions and contributing to the tool with people who have been doing this for 20 years—the best of the best.”

STENNIS SPACE CENTER

20 STENNIS EMPLOYEES SUPPORTED NESC WORK IN FY25

Stennis Space Center provided expert technical support to the NESC during 2025, including subject matter expertise in several of the NESC's TDTs. Experienced engineers in the Thermal Control & Protection, Systems Engineering, and Software TDTs were key participants in planning and strategy sessions for their TDT yearly face-to-face meetings. Other Stennis engineers became new, contributing members of the Materials and Avionics TDTs, joining existing members of Propulsion, Cryogenics, Human Factors, Aerosciences, Loads & Dynamics, Structures, and Mechanical Systems TDTs. As highlighted in their employees' profiles, Stennis has supplied early-career as well as late-career experts contributing to a variety of NESC assessments this year.

MICHAEL D. SMILES
NESC CHIEF ENGINEER
(Retired 2025)

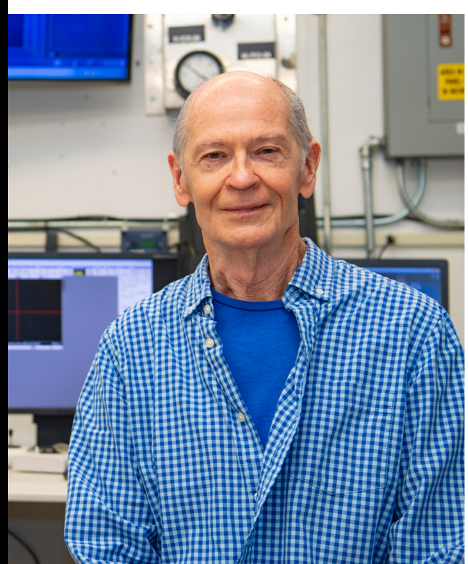
DR. KAMILI SHAW
ACTING NESC CHIEF ENGINEER

Luke Roger

The NESC recently leveraged Mr. Luke Roger's engine test experience for an assessment to address anomalies with a commercial provider's propulsion system. Roger works as a control systems engineer at the Stennis's A1 test stand where he tests the RS-25 engines used on SLS, the super heavy-lift rocket that is a key component of NASA's Artemis campaign.

Roger built a simplified adapter block at Stennis that he took to Marshall's environmental testing lab to help manufacture manifolds like those used by the provider. "We wanted to see if we could replicate the same anomalies seen in flight and test possible replacement seals," he said. With the test results, the assessment team was able to give the provider valuable data and offer potential mitigations.

Roger appreciated the opportunity to broaden his perspective. "I work as a ground floor engineer doing testing," he said, "but this assessment was a chance to pull back and look at the bigger picture. I loved working on that kind of project as an early career engineer and the chance to represent Stennis. It was a fantastic experience just to meet people from other centers, see how they do things, and work a test program where you had to think in terms of a programmatic solution."



H. Rick Ross

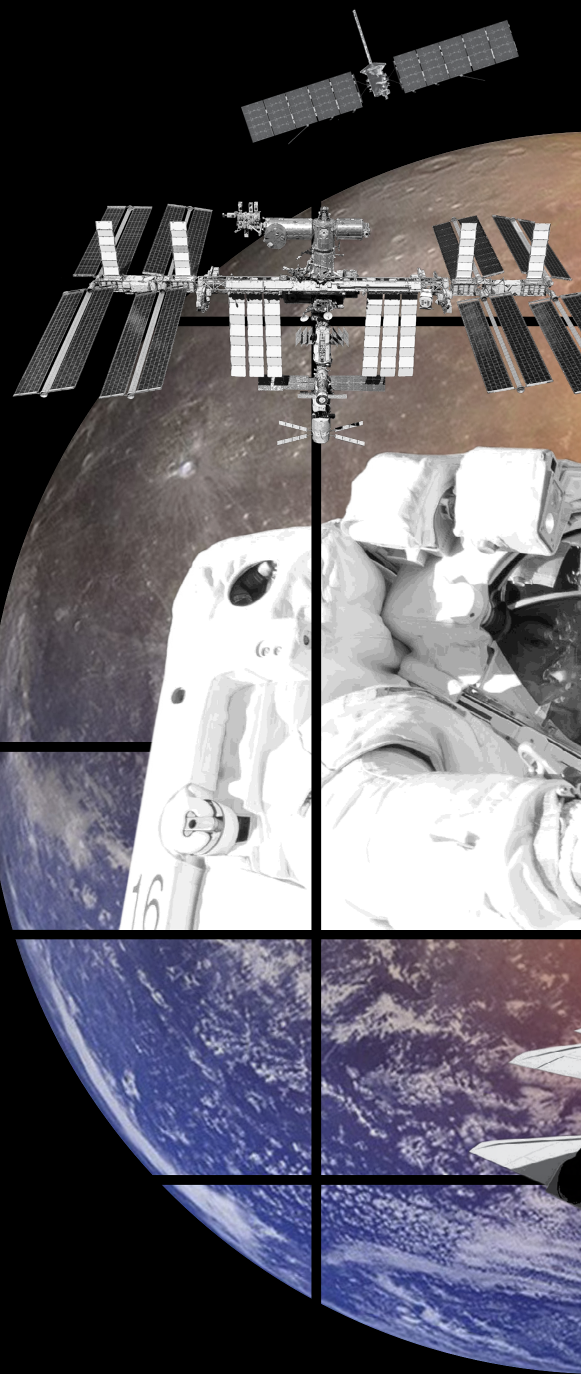
Mr. Harold "Rick" Ross remembers when he used to be the "young guy" in the Stennis Gas and Materials Science Lab. "Now I'm the old guy," he said. But the NESC is more than happy to have his 47 years of invaluable materials science expertise on hand. Now the lead for that same lab, Ross provides administrative oversight, technical management, and resource planning, and fields support operations requested by NASA. "I also do failure analysis and prepare reports and white papers. I just enjoy the variety of the work."

Ross also enjoys what he calls "going off road" to help the NESC with technical projects. He helped the Orion Program with tubing contamination issues and developed test protocols for determining which potential candidate would best replace a precision cleaning solution being phased out of production. "We came up with another solvent for precision cleaning, and I presented the results to the Department of Defense. I was the primary author of the Rocket Propulsion Test Precision Cleaning Standard and implemented that solvent into our applications at Stennis," said Ross. "I also worked with the NESC to understand discrepancies in mechanical impact tests that resulted in updates to the American Society for Testing and Materials standard."

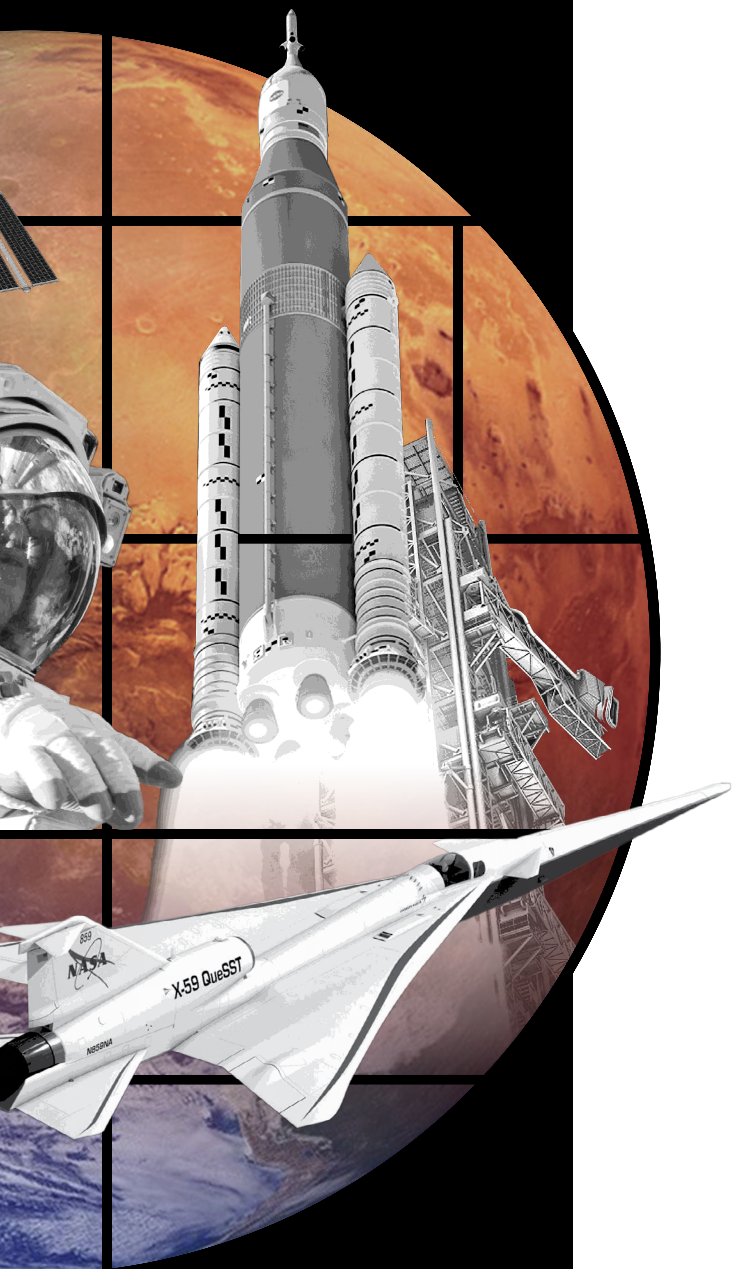
"I'm lucky that no two days are quite the same," he said. "I really enjoy performing failure analysis on materials and investigating issues associated with propulsion testing. It keeps it interesting."

NESC KNOWLEDGE SHARING

WORKSHOPS, MENTORING HIGHLIGHTS, AND KNOWLEDGE PRODUCTS



The NESC has completed nearly 1,400 assessments for NASA programs and projects. These assessments have generated a wealth of knowledge and lessons learned that not only benefit individual programs or projects, but often the broader engineering community and agency as a whole.



FY25 NESC-RELATED EVENTS

The NESC is dedicated to enhancing NASA's engineering disciplines with workshops and other events in order to facilitate discussion of hot topics or concerns requiring broad perspectives from both within and outside the agency.

- **DoD-NASA Lidar Technical Interchange Meeting**
- **NASA Aerospace Battery Workshop**
- **Spacecraft Anomalies and Failures Workshop**
- **NESC Lunar Cold Electronics Technical Assessment Meeting**
- **Applied Space Environments Conference (ASEC)**
- **NASA Stuctures, Loads and Dynamics, Materials, and Mechanical Systems (SLAM²S) Face-to-Face**
- **NASA Thermal and Fluids Analysis Workshop (TFAWS)**
- **NASA Agile Technical Interchange Meeting**
- **NASA Systems Engineering Technical Interchange Meeting**

View upcoming events at
nasa.gov/nesc/workshops

NESC ENGAGES EARLY CAREER ENGINEERS IN HANDS-ON WORK OPPORTUNITIES

Lucy Somervill (front) and Jessica Schwend investigate a pressure sensor anomaly under the mentorship of Dr. Robert Youngquist.

In late 2023, the Commercial Crew Program (CCP) came to the NESC looking for sensor expertise. One of their vendors had been experiencing pressure sensor anomalies, and early investigations hadn't been able to home in on the root cause. During 2024, continued testing at the vendor's facility and by the NESC also failed to determine the source of the anomaly.

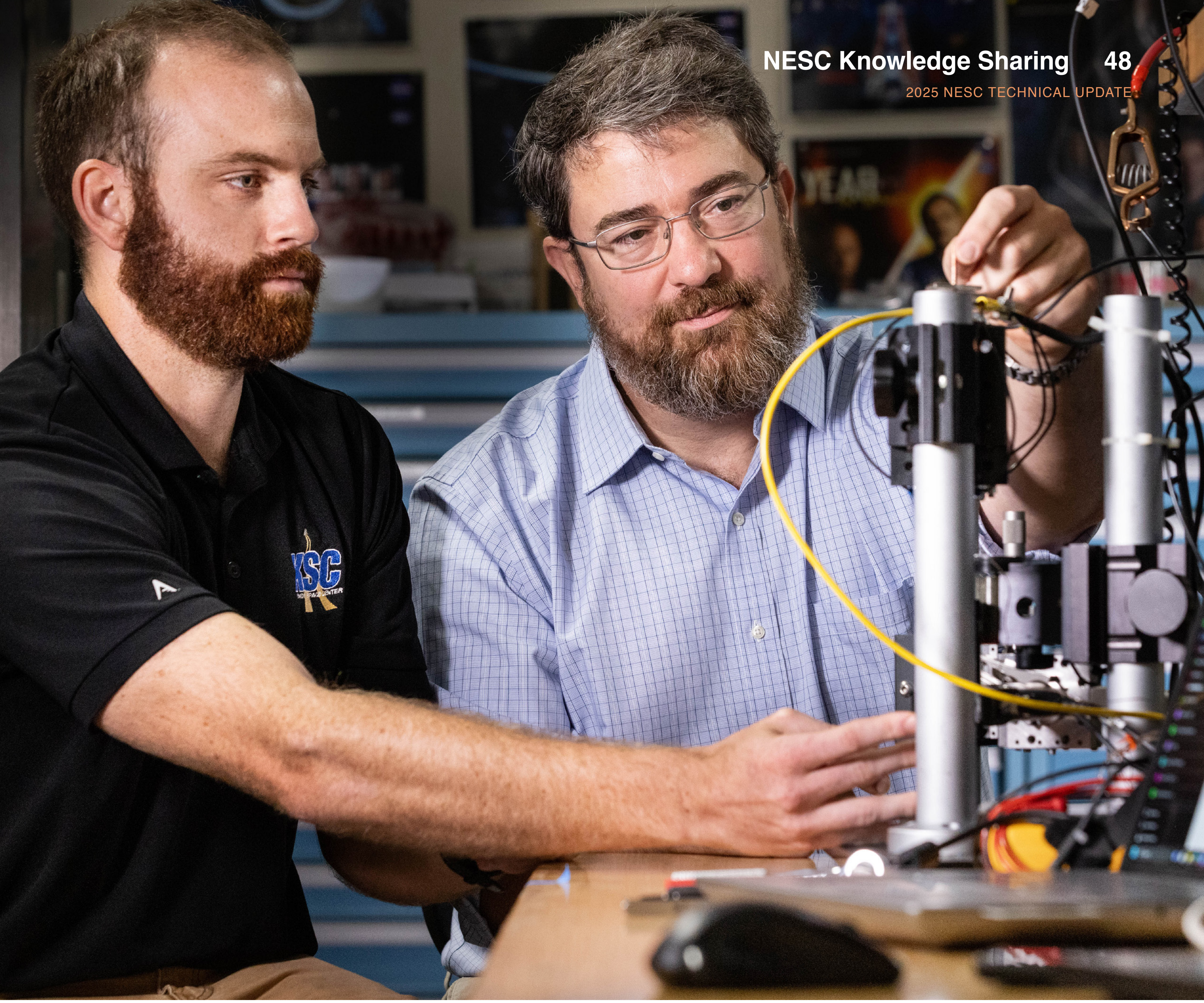
In late 2024, Dr. Robert (Bob) Youngquist had a theory about what might be causing the problem and suggested a modified test approach. He saw this as a perfect learning opportunity for early career engineers (ECE) and arranged for the NESC and CCP to jointly fund a team of mentors and young employees to address this issue.

"This was a flight hardware problem that these young engineers could work," said Youngquist, who is always looking for ways to provide ECEs with hands-on engineering experience. Along with Drs. Douglas Willard, Christopher Biagi, and Tracy Gibson from Kennedy Space Center, he turned the project into a mentoring opportunity. "We had several ECEs at our kickoff meeting, and they took this project and ran with it."

Assembling the Team

Jessica Schwend fit the very definition of an ECE when she was tapped for the sensor assessment. Following NASA internships at Kennedy, she had just converted to full time work in the Applied Chemistry Lab (ACL) in May 2024. Though she'd never met Dr. Youngquist (Dr. Bob, as he is known by the ECEs), she knew he had established Kennedy's Applied Physics Lab, a neighboring group, and led it for many years.

"I was a little intimidated at first," she admitted, stepping into her first leadership role as the test conductor. "I was asked to put together a test setup that would allow us to investigate the sensor and hopefully recreate the anomaly in the lab." Typically working in technology development, she said, "Proof of concept tends to fly under the radar of a NASA mission. This work had such a different application from what I'm usually doing."



Left to right, Stefan Tomović and Dr. Christopher Biagi evaluate pressure transducers for the NESC. The probe is designed to improve the detection of thruster pressure sensor anomalies for the agency's Commercial Crew Program.

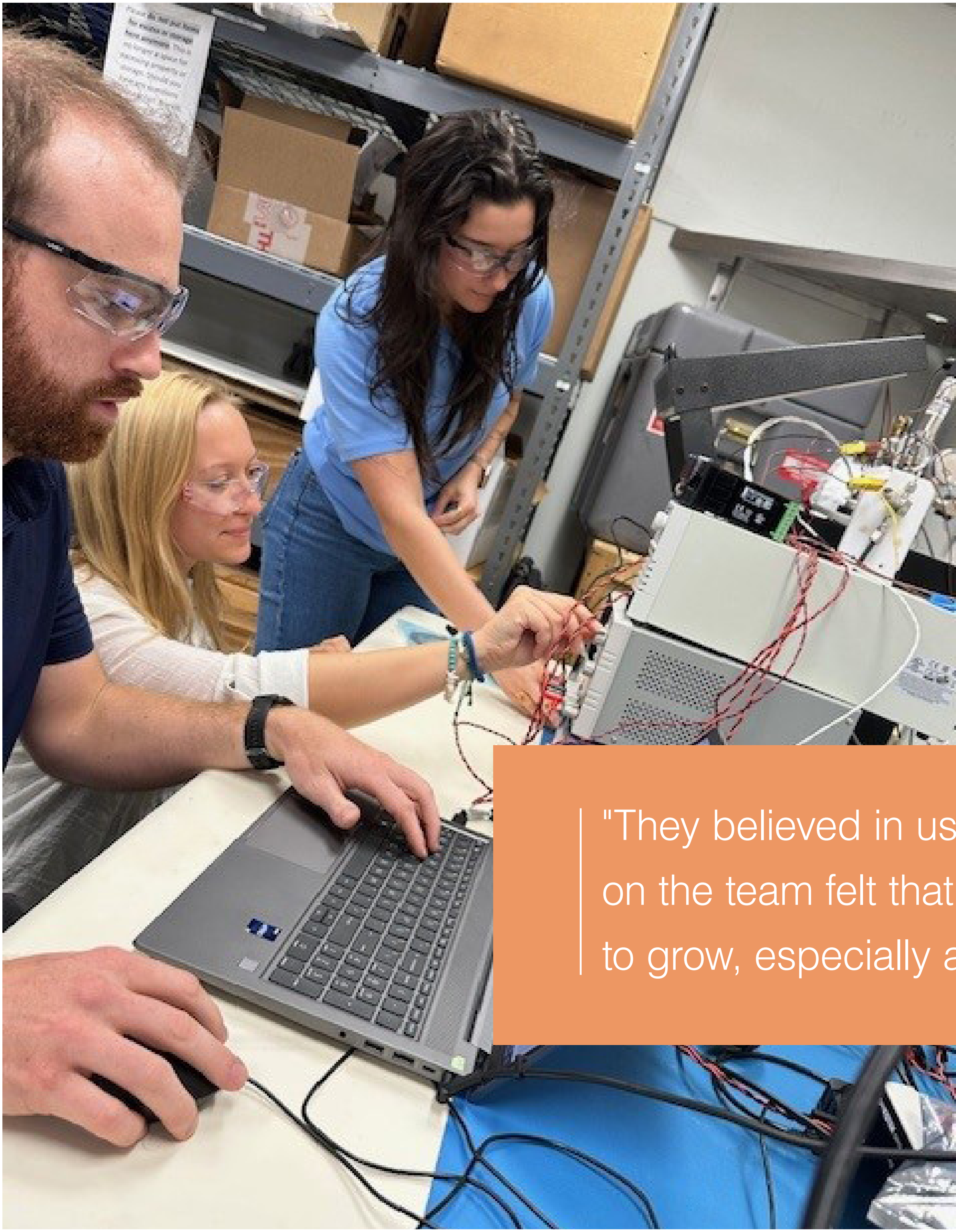
For many engineers who work in research and development, projects can be long-term, taking years to see meaningful results. This project offered the chance to tackle a real-time problem, whose solution would have an immediate impact for CCP.

"Sometimes it just takes so long, so it's good to get these little wins in your career. It keeps you motivated," said Stefan Tomović, an electrical engineer with nearly 5 years at NASA with experience building mass spectrometers and other hardware for NASA missions. Assigned as the test lead, he helped Schwend with developing test fixtures, data acquisition, and organizing procurements.

Lucy Somervill had worked full time in the ACL for 8 months when she joined Youngquist's team. A chemical engineering major with a background in polymers, she was excited to delve into the physical properties of the different materials inside the

> "This was a flight hardware problem that these young engineers could work."

continued



"They believed in us
on the team felt that
to grow, especially a

From left, Stefan Tomović, Lucy Somervill, and Jessica Schwend.

sensor. "Most of my other projects are very chemistry based, and this project was too, but it tied into the bigger picture of testing the pressure systems, understanding how these materials enable the sensor, and problem solving around that."

Youngquist also brought in Dr. Kenneth Engeling from the ACL to consult and mentor the team, though with just five years at NASA, he was considered an ECE as well. "As interns, Schwend and Somervill both worked with me before converting to full time," he said. "They're excellent. They're definitely the right people for the job." Though Engeling worked behind the scenes helping with lab access and equipment, he was always accessible for questions and advice.

Excited to Get to Work

"I remember when we first started working on this project, I'd be driving home excited about what we would do the next day. And one day I thought, why am I so excited to test a pressure sensor?" Schwend laughed. "A pressure sensor could be used anywhere. But because of the application and because of the bigger picture, it really got us excited at the beginning and kept us excited."

Every week the team would meet to discuss their progress. "Sitting in meetings with Dr. Bob and the team, I just tried to soak it in," said Somervill. "Our mentors were amazing. They were always encouraging us to come up with our own ideas and theories, but if we ever needed an ear, they were there. They believed in us, and I think everybody on the team felt that. It's a really good place to grow, especially as an early career. You don't feel scared to try new things, and you know that these people will have your back."

, and I think everybody
. It's a really good place
as an early career."

Tomović readily agreed. "I felt like my IQ went up just sitting in the same room. Dr. Biagi, Dr. Bob, and Dr. Willard made time to work with you and struggle with you because we're all still learning. They've adopted that mindset to always be learning, and it's good to be in an environment where it's okay to be wrong." The work was certainly challenging, Tomović said. "It pushed you out of your comfort zone, and that was good. Dr. Bob let us make mistakes, not boneheaded ones, but if we wanted to try something, he let us. That's great, because I think you learn a lot through just doing."

Students Become the Teachers

After testing was complete, Dr. Youngquist got the answer to the question he had asked the team to solve. "They evaluated the sensors, characterized them, and put them through all the tests that I had laid out for them. And they came back to me and said, 'Bob, you're wrong. Your theory is wrong.'"

Schwend was the one to deliver the news, though a bit gentler than Youngquist described. "I got the result that I wasn't expecting, and that I didn't really want to get, because then you throw a wrench in everything," she said. She remembers that morning meeting with Dr. Bob and the team. "So, I ran this test," she told them, "and actually, it's a little bit different than what we think."

But Youngquist couldn't have been more thrilled, albeit a bit humbled. "The problem was actually simpler than I had suspected," he said. "The team demonstrated, for the first time in a lab environment, the phenomenon that the vendor was seeing in flight. That was a big deal! They finally figured out what was going on," showing that it was a combination of pressure and temperature that was causing the anomaly.

"It definitely wouldn't have been possible without Dr. Bob's ideas and his initial theory," said Schwend. As the earliest career engineer in the group, she credits not only her mentors but the other ECEs on the team for all the knowledge she absorbed during the project. "I learned from them every time we were in the lab, every time we were testing. It was such a great balance between them supporting me, teaching me, and also pushing me to try new things. It's something really special at NASA that we have this focus on pushing early careers to put themselves out there at the front of the line. I've learned so many technical skills, as well as things about career and life from the whole team. It's really been great."

The team subsequently expanded their testing to include another vendor, raising the bar another notch on the work that has been so beneficial for CCP and its vendors. Youngquist said the team was nominated for an NESC Group Achievement Award for their significant contributions.

"I think there are certain projects that are practically ideal for young engineers, and this happened to be one of them," he said. "We're all basically letting them run with things, but when they run into places where they are unclear or unsure of how to do something, we're stepping in and training and teaching as a mentor should." ●

NESC KNOWLEDGE PRODUCTS

The NESC is engaged in activities to identify, retain, and share critical knowledge. To disseminate that knowledge—within NASA, industry, and academia—the NESC maintains a wide variety of knowledge products that can be readily accessed.

Engineering Reports

Documented results of independent testing and analysis delivered to the requesting stakeholders.
ntrs.nasa.gov

Lessons Learned

Useful knowledge gained from experience.

- ***Lessons Learned Information System*** llis.nasa.gov
- ***NESC Academy*** nescacademy.nasa.gov

Technical Bulletins

Critical engineering information or best practices captured in a one-page, quick-read format.
nasa.gov/nesc

Innovative Techniques

New and creative engineering approaches developed during NESC technical activities. nasa.gov/nesc

Journal Articles and Conference Papers

Citations for publications summarizing NESC technical activities for discipline-specific audiences.
nasa.gov/nesc

Technical Updates

Annual reports of NESC technical activities.
nasa.gov/nesc

NASA Engineering Network (NEN)

An online community where NASA employees can collaborate with peers and discipline experts.
nen.nasa.gov

NESC Academy

NASA Engineering and Safety Center

Engineering Insight, On-demand

The NESC Academy presents live and on-demand content from researchers, engineers, and field experts in 19 technical disciplines relevant to the design, development, test, and operation of NASA programs and projects. It hosts more than 1,200 videos containing interviews, tutorials, lectures, and lessons learned in an engaging format with powerful search capabilities and downloadable course materials.

In FY25: **185 Videos Published, 31 Live Webinars**

Most Viewed Videos by Discipline FY25

AEROSCIENCES
Aerodynamic Performance Testing

AVIONICS
Fundamentals of Electromagnetic Compatibility

CRYOGENICS
The Zero-Boil-Off Tank (ZBOT) Experiment

ELECTRICAL POWER
High Voltage Engineering Techniques for Space Applications

ENVIRONMENTAL CONTROL & LIFE SUPPORT
Space Radiation Environments

FLIGHT MECHANICS
Dynamics: Introduction to Kane's Method

GUIDANCE, NAVIGATION, & CONTROL
Fundamentals of Spacecraft Attitude Control

HUMAN FACTORS
Humans to Mars, But How Many? A Historical Review of Crew Size Determination for Mars Missions

LOADS & DYNAMICS
Shock & Vibration: 01. Natural Frequencies, Part 1

MATERIALS
Shape Memory Alloys

MECHANICAL SYSTEMS
An Overview of Fastener Requirements in the New NASA-STD-5020

NONDESTRUCTIVE EVALUATION
ISS Inspection Capabilities and Challenges

PROPULSION
Generalized Fluid System Simulation Program (GFSSP) Training Course

SENSORS & INSTRUMENTATION
Lidar for NASA Applications

SOFTWARE
How to Unit Test and Use GCOV for MC/DC

SPACE ENVIRONMENTS
(MOWG) NASA Robotic CARA Probability of Collision

STRUCTURES
Sandwich Structures Failure Modes and Their Prevention

SYSTEMS ENGINEERING
Model-Centric Engineering, Part 1: Model-Based Systems Engineering

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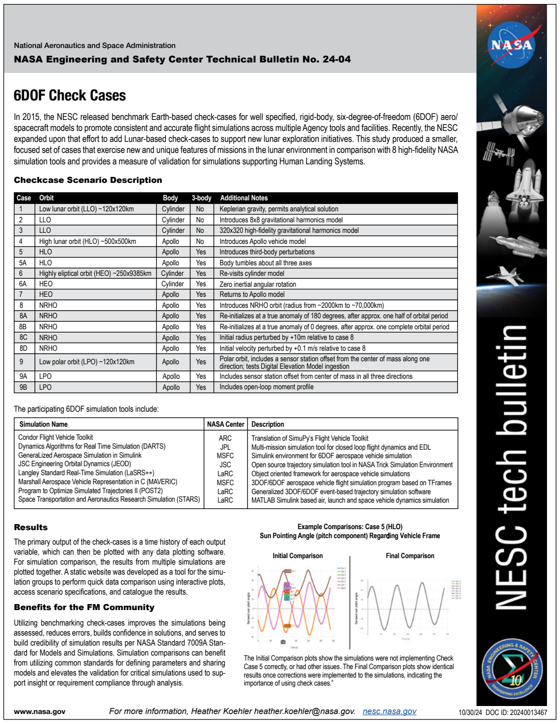
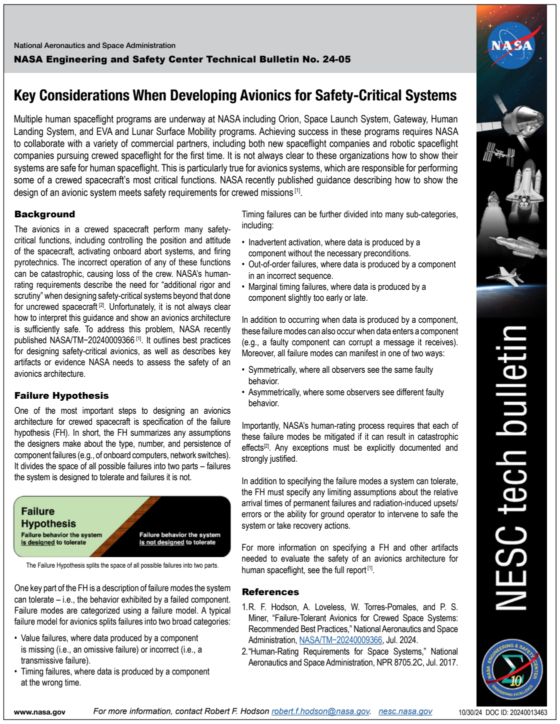
FY25 TECHNICAL BULLETINS


National Aeronautics and Space Administration
NASA Engineering and Safety Center Technical Bulletin No. 24-04
6DOF Check Cases

TECHNICAL BULLETIN 24-04

6DOF Check Cases

In 2015, the NESC released benchmark Earth-based check-cases for well specified, rigid-body, six-degree-of-freedom (6DOF) aerodynamic/spacecraft models to promote consistent and accurate flight simulations across multiple agency tools and facilities. Recently, the NESC expanded upon that effort to add lunar-based check cases to support new lunar exploration initiatives. This study produced a smaller, focused set of cases that exercises new and unique features of missions in the lunar environment in comparison with 8 high-fidelity NASA simulation tools and provides a measure of validation for simulations supporting the Human Landing System.


National Aeronautics and Space Administration
NASA Engineering and Safety Center Technical Bulletin No. 24-05
Key Considerations When Developing Avionics for Safety-Critical Systems

TECHNICAL BULLETIN 24-05

Key Considerations When Developing Avionics for Safety-critical Systems

Multiple human spaceflight programs are underway at NASA including the Orion, Space Launch System, Gateway, Human Landing System, and EVA and Lunar Surface Mobility Programs. Success in these programs requires NASA to collaborate with a variety of commercial partners, including new spaceflight companies and existing companies with robotic spaceflight experience, both pursuing crewed spaceflight for the first time. It is not always clear to these organizations how to show their systems are safe for human spaceflight. This is particularly true for avionics systems, which are responsible for performing some of a crewed spacecraft's most critical functions. NASA recently published guidance describing how to show the design of an avionics system meets safety requirements for crewed missions.

Critical engineering information or best practices captured in a one-page, quick-read format.

National Aeronautics and Space Administration

NASA Engineering and Safety Center Technical Bulletin No. 25-01

The Need to Bake Out Silicone Based Thermal Control Coatings

The NASA Engineering and Safety Center (NESC) has reviewed flight, ground test, and published data on ultraviolet-induced degradation of silicone based thermal control coatings. Analysis has shown, for at least one silicone coating, that bake-out plays an important role in ultraviolet (UV) degradation, indicating that UV interaction with paint volatiles, and not the structural material, is the primary source of coating discoloration.

Background

Spacecraft temperature is primarily determined by the absorptivity and emissivity of the vehicle's coating. Absorptivity is the fraction of the sun's irradiance that is absorbed, and emissivity determines the amount of infrared power that is emitted. The combination of these properties, along with additional heat from internal sources and other external radiation sources, determines the spacecraft's thermal environment. Choosing an appropriate coating, referred to as a thermal control coating, is key to keeping the vehicle within a desired temperature range. However, these coatings can degrade, (i.e., darken), in low earth orbit (LEO), primarily due to solar UV exposure, complicating the choice of coating. Zinc-oxide (ZnO) scatterers in a silicate binder are among the most stable white coatings but suffer from poor adherence. Replacing the silicate with organic silicone improves paint mechanical properties, but optical property measurements of UV exposure stability for ZnO-silicone coatings have been widely divergent. This led to a request that the NESC resolve the variations to better predict the stability of specific ZnO-silicone coatings in LEO. Testing of coupons began in FY25 and will complete in FY26.

Discussion

Many silicone-based thermal control coatings have been evaluated in ground simulation chambers and tested in space since the mid-1960s [ref 1, 2], demonstrating a wide range of UV degradation rates, sometimes for the same formulation. Ground testing a particular ZnO-silicone coating in two different facilities yielded degradation rates that differed by more than a factor of 6. This is similar to variations seen in a round-robin test of ground UV exposure facilities in the 1960s [ref. 2] and casts doubt as to the usefulness of ground testing to predict flight performance. In this case, consideration of the differences between the two ground tests along with partial retesting, pointed to the presence of volatiles as the source of the difference. In one facility, the samples were baked out prior to testing, removing most of the volatiles in the paint, but in the other facility the samples were not baked out. This indicated that the primary source of absorptivity change was UV interaction, not with the silicone substrate material, nor with the ZnO scatterers, but with the volatiles. In addition, the two facilities had different UV irradiance spectra, which may have contributed to the large degradation variation [ref.3].

A literature search was conducted and, surprisingly, only one paper was found that tested ZnO-silicone paint degradation with and without a prebake [ref. 1]. In this publication, paint S-31 without a bake-out was exposed to 1780 equivalent solar hours (ESH) of UV and saw a change in absorptivity of 0.02, but a sample that was baked at 260°C (500°F) for 1 hour and then exposed to 1780 ESH saw only a change of 0.006. In a second case, two S-33 samples were exposed to 4170 ESH, both with a one hour 150°C prebake out and one with an additional one hour 260°C prebake. The one with the single bake-out saw an absorptivity change of 0.02 and the one with the additional bake-out saw a change of only 0.011, comparable to the "best zinc oxide…silicate paint."

Testing of ZnO-silicone paints has been conducted on the Materials International Space Station experiment (MISSE), [ref. 4], showing a similar reduction in UV degradation for samples that were baked out prior to flight and those that were not. In MISSE-19, a sample of a ZnO-silicone paint that was baked out showed a net change in absorptivity of 0.011 (Wake position) versus 0.27 for a sample of the same paint in the Zenith position that was not baked out. There is positional variation that may have contributed to this difference, but the removal of volatiles is a likely contributor.

Finally, spacecraft testing of the same ZnO-silicone paint has shown very low UV degradation over extended periods in LEO which is interesting given that the paint on the spacecraft is not baked out. Aerodynamic heating on ascent is insufficient to remove the volatiles, however, surface temperatures while in orbit are sufficient. On the spacecraft, the paint covers an insulative, micrometeor protective layer allowing the paint to heat in sunlight (unlike the MISSE samples that are painted on aluminum disks mounted to an aluminum tray). This heating in orbit provides a nearly continuous bake-out, removing not only residual volatiles, but newly formed volatiles created by UV induced decomposition of longer chain molecules.

Comparing outgassing data to the bake-out conditions further supports the proposition that volatiles within the paint, and not the binder or scatterers, discolor under solar UV exposure. Indicating that prebake or, in-flight continuous baking, is a key requirement for long duration performance of a specific family of ZnO-silicone based thermal control coatings.

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1. Ref. Zerlaut, G. A., Y. Harada, and E. H. Tompkins. "41. Ultraviolet Irradiation of White Spacecraft Coatings." *In Symposium on Thermal Radiation of Solids*, vol. 55, p. 391. Scientific and Technical Information Division, National Aeronautics and Space Administration, 1965.
2. Arvesen, J. C., C. B. Neel, and C. C. Shaw. "44. Preliminary Results From a Round-Robin Study of Ultraviolet Degradation of Spacecraft." In *Symposium on Thermal Radiation of Solids*, vol. 55, p. 443. Scientific and Technical Information Division, National Aeronautics and Space Administration, 1965.
3. ARVESEN, J. "Spectral dependence of ultraviolet-induced degradation of coatings for spacecraft thermal control." In *2nd Thermophysics Specialist Conference*, p. 340. 1967.
4. Kenny, Mike, Robert McNulty, and Miria Finckenor. "Further Analysis of Thermal Control Coatings on MISSE for Aerospace Applications." In *National Space and Missile Materials Symposium*, no. M09-0535. 2009.

Figure 1. A UV exposure facility at the Marshall Space Flight Center

Figure 2. A post exposure MISSE 2 sample tray [ref. 4]

NESC tech bulletin

www.nasa.gov *For more information, contact Analytical Mechanics Associates, Inc.; robert.c.youngquist@nasa.gov. nesc.nasa.gov* 09/12/25 DOC ID: 20250008144

TECHNICAL BULLETIN 25-01

The Need to Bake Out Silicone-based Thermal Control Coatings

The NESC has reviewed flight, ground test, and published data on ultraviolet (UV)-induced degradation of silicone-based thermal control coatings. Analysis has shown, for at least one silicone coating, that bake-out plays an important role in UV degradation, indicating that UV interaction with paint volatiles, and not the structural material, is the primary source of coating discoloration.

Explore all NESC Technical Bulletins at **nasa.gov/nesc/knowledge-products/nesc-technical-bulletins/**

FY25 LESSONS LEARNED

Hydrofluorocarbon (HFC) and Hydrochlorofluorocarbon (HCFC) Fire Suppressants Exacerbate Fires in Space Vehicles and Require Extended Dwell Time to Achieve Extinguishment

- **DRIVING EVENT**: After flammable materials were identified in human-rated spacecraft, an effort was undertaken to evaluate the effectiveness of the fire suppression system on the materials of concern. The vehicle design used a commercial-off-the-shelf portable fire extinguisher containing HFC-227ea. Testing of the suppressant with the materials of concern revealed the described issues.
- **LESSON LEARNED**: Hydrofluorocarbon fire suppressants increase the burn rate of solid materials, relative to the burn rate with no suppressant present, until extinguishment is achieved and require extended dwell time due to their inherent chemistry and extinguishment mechanism.
- **RECOMMENDATION**: HFC and HCFC suppressants should not be used in spacecraft.

For more information, visit **llis.nasa.gov/lesson/34301**.

FY25 INNOVATIVE TECHNIQUES

A Combination of Techniques Leads to Improved Friction Stir Welding

The NESC developed several innovative tools and techniques during an assessment to find the root cause of poor tensile strength and low topography anomalies (LTA) in welds formed using a solid-state welding process called self-reacting friction stir welding (SRFSW).

Using a combination of machine learning, statistical modeling, and physics-based simulations, the assessment team helped improve the weld process and solve both issues, lifting constraints that had been placed on flight hardware.

Developing Techniques for LTA Detection

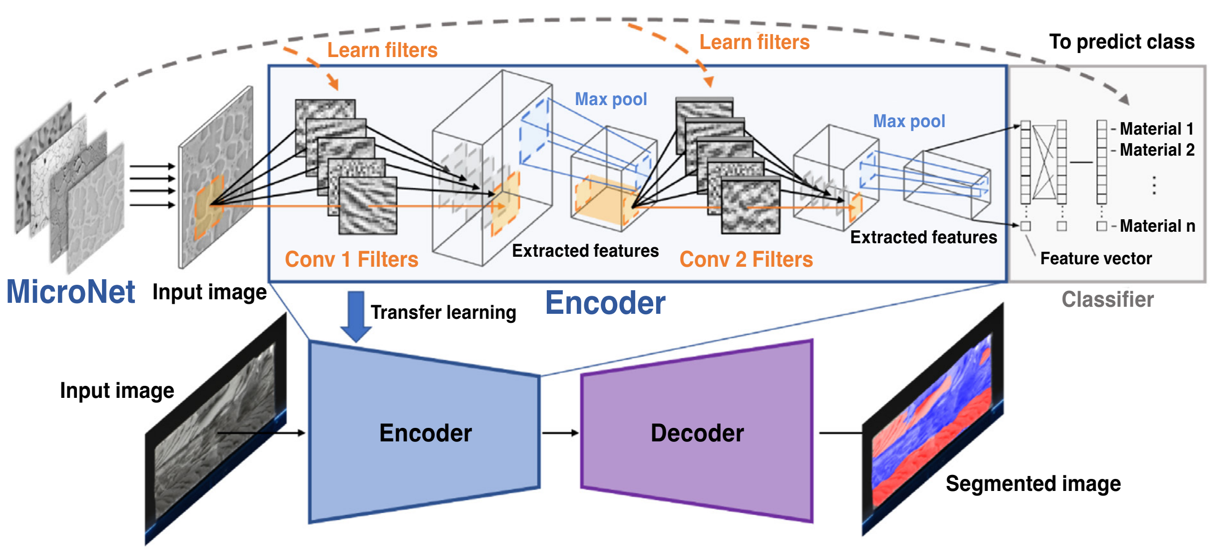
Determining the root cause of poor tensile strength welds and LTA observed on the weld fracture surfaces involved several techniques:

- **Deep Learning for LTA Detection:** The NESC team developed a machine-learning model to detect and segment LTA in weld images. The model was trained on images annotated by metallurgy experts, with a majority-vote consensus to resolve disagreements. The team then developed an accompanying standard operating procedure for image capture to improve robustness and reduce bias. This model was built on previous NASA work to develop specialty microscopy analysis foundation models by pretraining on 100,000+ microscopy images. This step was crucial to linking process parameters with LTA occurrence in an objective, nonbiased way.

- **Integrated Data-Ingestion Framework:** SRFSW is a complex process with many interacting variables. The weld process produces a large amount of data with diverse data types that include dozens of tabular process parameters, dozens of sequential data streams from the production tool, fracture and weld cross-section images, and mechanical-test lab data. A Python-based framework was developed to automatically ingest and validate these diverse data and compile them into a single master spreadsheet and a database. This tool reduced manual effort, minimized transcription errors, and improved data quality for downstream analysis. The team delivered the tool to stakeholders for their ongoing use.

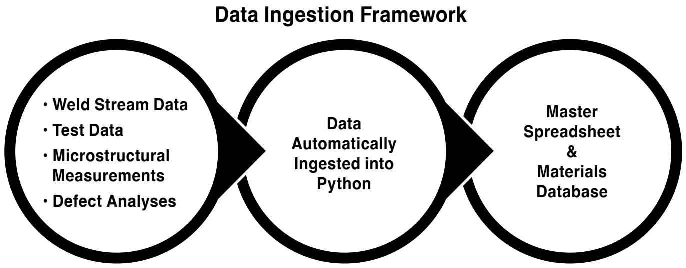
- **Data Analysis Web Application:** A new web-based visualization and analysis tool allowed engineers and subject matter experts to quickly explore the integrated dataset for faster hypothesis testing and more intuitive insight generation throughout the investigation.

- **Space-Filling Design of Experiments:** Because SRFSW involves complex, nonlinear relationships between process parameters, the team found traditional factorial designs were insufficient and implemented a space-filling



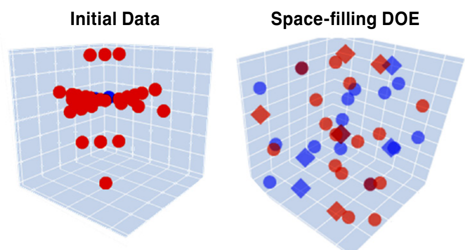
The team eliminated issues with manual identification of LTA by training a neural network to detect LTA from images of fracture surfaces, pretraining an encoder on a large NASA dataset of microscopy images called MicroNet.

New and creative engineering approaches developed during NESC technical activities.



Because SRFSW is an extremely data-rich process, no single dataset for these various data streams existed prior to this assessment. This data ingestion and analysis pipeline links processing parameters, microstructure, and mechanical performance at every inch of the weld.

design of experiments (DOE) to efficiently explore the full parameter space. These data-trained machine-learning models capture the underlying weld behavior. The team also developed a software tool for generating such designs and shared it with stakeholders.



Space-filling DOE uniformly covers the process space and is better for training machine learning models.

- **Physics-Based SRFSW Simulation:** Creating a computational model of the SRFSW process simulated weld conditions, microstructure evolution, and resulting properties, offering insight into aspects of the weld process that are inaccessible to physical sensors. This enhanced understanding and guided improvements.

Determining LTA Root Cause

Using these tools and analyses, the team identified two root causes for the LTA and poor tensile strength:

1. **Overly aggressive post-weld surface preparation** in production reduced weld strength.
2. **Weld power input outside the optimal range** led to inconsistent welds and increased risk of LTA.

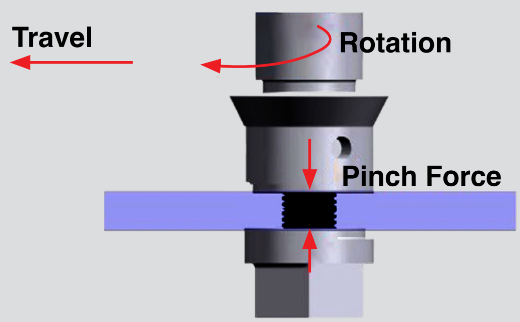
The process models helped define a target weld power input window and recommended how to adjust primary control parameters to reliably achieve that target. Follow-up production tests confirmed that these adjustments could be implemented with high precision, eliminating both low-strength welds and LTA. ●

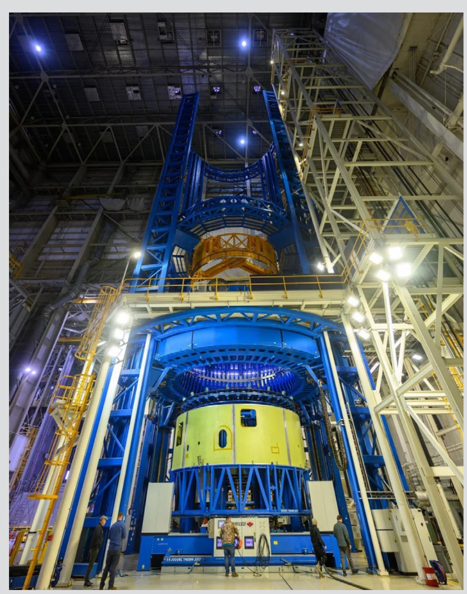
For information, contact Donald S. Parker. donald.s.parker@nasa.gov
References: NASA/TM-20240016466 and NASA/TM-20230010624

Friction Stir Welding 101

In SRFSW, a rotating pin is plunged into the seam between two metal plates, generating heat through friction that fuses the sheets together without melting the material. This technique produces stronger joints than traditional welding and enables the use of high-performance but traditionally non-weldable alloys like Aluminum 2219.

The SRFSW technique uses no blowtorches or solder because friction stirs the materials together at a molecular level.





NASA's Friction Stir Welding lab resides inside NASA's Michoud Vertical Assembly Center in New Orleans and is being used to join major components of the SLS rocket.

FY25 INNOVATIVE TECHNIQUES

NESC Develops Method for Estimating Risk When Reducing NDE

Performing nondestructive evaluation (NDE) can have both cost and schedule impacts, leading some to question whether descoping (i.e., reducing or eliminating) NDE inspections on certain spaceflight hardware could be possible. However, this approach would be counter to NASA's Technical Standard NASA-STD-5019A, which outlines the spaceflight system requirements for establishing a fracture control plan—one that relies on design, analysis, testing, NDE, and tracking of fracture-critical parts to verify damage tolerance and mitigate catastrophic failure.

Under the 5019A framework, damage smaller than the NDE detection capability is assumed to exist, but through analysis or test, the part being evaluated must be shown to survive the required service life. In practice, NDE's role is to screen out flaws that otherwise may result in failure. However, in some cases, descoping NDE from the damage tolerance verification process could be useful and still provide the required level of safety.

The NESC conducted an assessment to help answer the question of whether rationale could be found for achieving an equivalent risk posture without using the traditional 5019A approach to damage tolerance. The objective was to develop a probabilistic analysis method that would allow NASA programs and projects to estimate risk associated with descoping the NDE requirements of single-wrought materials. This effort included using historical data to demonstrate the method, performing sensitivity studies, and identifying the minimum supporting data that would be required for approving a descoping request.

Descoping NDE from Damage Tolerance

Damage tolerance is typically treated as deterministic: an NDE detection threshold is established as a fixed flaw size with an associated binary outcome (flaw exists/does not exist), and failure is based on a conservative analysis or test with a binary result (pass/fail). However, damage tolerance is rooted in the following probabilities:

- $P(A)$: Probability that a flaw of a given size exists,
- $P(D_0|A)$: Probability that this flaw will be missed by NDE, and
- $P(F|D_0,A)$: Probability that a flaw results in failure given that it exists and was missed by NDE.

These are combined into the joint failure probability:

$$P(F,D_0,A) = P(F|D_0,A)P(D_0|A)P(A)$$

Damage tolerance is based on the idea that analysis and testing suggests a near-zero probability of failure below a critical initial flaw size (a_{CIFS}) shown by the green (lower) arrow in Figure 1, and NDE results in a near-zero probability of missing a flaw above some detectability threshold (a_{NDE}) shown by the yellow (upper) arrow in Figure 1. If these two areas overlap, then the part is damage tolerant, with a near-zero failure probability regardless of underlying probability of flaw existence, i.e., conservatively assuming that $P(a > a_{CIFS})$=1 for any flaw size does not impact the conclusion. However, if NDE is descoped, it removes the right arrow from Figure 1, and risk will increase to a value proportional to the probability $P(a > a_{CIFS})$.

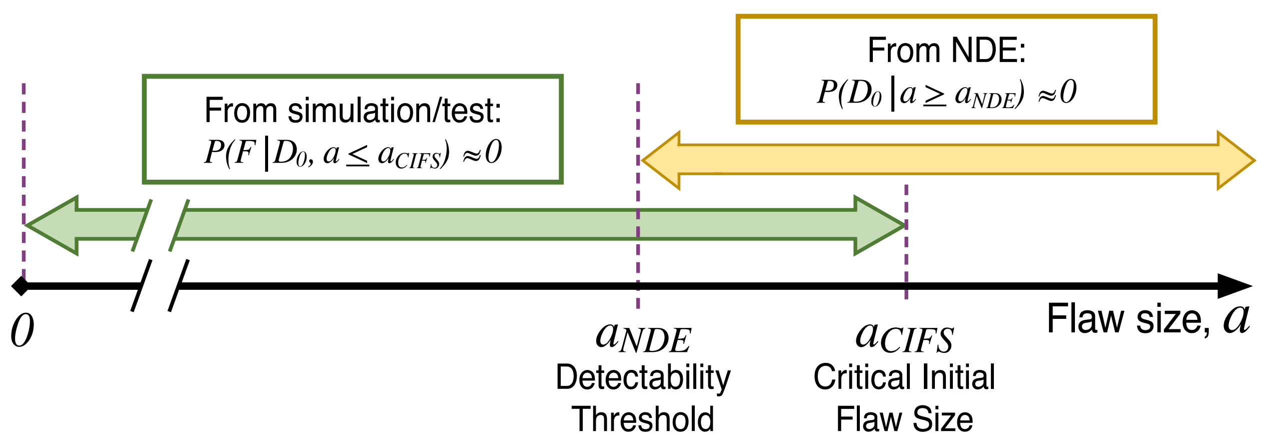


Figure 1. A probabilistic interpretation of damage tolerance

New and creative engineering approaches developed during NESC technical activities.

Estimating $P(a > a_{CIFS})$ may be intractable without expensive, high-resolution methods to characterize the frequency of flaw occurrence at a particular size for a given part. Alternatively, it may be possible to estimate $P(a \geq a_{NDE})$, the probability of a detectable flaw existing. Assuming that a part of interest is shown to be damage tolerant prior to any NDE descope (i.e., satisfying NASA-STD-5019A), it can be assumed that (1) historical inspection data are available, and (2) $a_{NDE} \geq a_{CIFS}$, due to the required overlap in Figure 1. As such, it was proposed that the frequency of historical finds could be used to estimate a 95% upper confidence bound on $P(a \geq a_{NDE})$ and thus an estimate of the risk associated with descoping.

To demonstrate the risk-evaluation framework, the NESC gained access to a historical NDE database comprising 33,630 bolt-hole inspections over a 3-year period. In total, six crack-like features were found by NDE. Accounting for uncertainty due to sample size yielded a 95% confidence upper bound of $P(a \geq a_{NDE})$ = 0.04% for each hole. In the proposed method, it is conservatively assumed that if a flaw exceeding the CIFS exists, then it will lead to structural failure. While conservative, this assumption was necessary based on the limitations of the database in that it lacked detected flaw sizing. Based on this assumption, $P(a \geq a_{NDE})$ = 0.0004 yields a structural reliability of approximately 0.9996 (expressed as 3.4 "nines").

The results are illustrated graphically in Figure 2. In this case study, increasing the number of inspections in the dataset to 100,000 (i.e., multiplying by a factor of 3) marginally increases the number of nines to 3.5. At the observed NDE rejection rate, 4 nines of reliability are not achievable even with infinite samples and zero uncertainty. It is expected that the rejection rates and sample sizes in this case study are on the order of magnitude of what would be observed and available in practice. Since 2 nines or less would equate to a significant increase relative to the baseline risk for NASA Human Spaceflight Programs, a minimum sample size of 5,000 inspections is needed at an NDE rejection rate of 0.04%.

There are necessary assumptions underpinning this methodology. First, time-invariant process control is required to ensure that estimated probabilities from historical inspections are predictive of future probabilities after descope. Ensuring consistency during the data collection period is a first step in verifying existing controls, and continued monitoring is necessary to verify that the process remains time-invariant. Second, while aggregating data across multiple parts can increase the inspection sample size and decrease uncertainty in estimated rejection rates, it requires aggregation rationale via qualitative and quantitative assessments of similitude. The methodology developed by the NESC is intended to be a component of a comprehensive fracture control evaluation by the NASA Fracture Control Board and the responsible Technical Authority. ●

For information, contact Patrick E. Leser. patrick.e.leser@nasa.gov
Reference: NASA/TM-20250004074

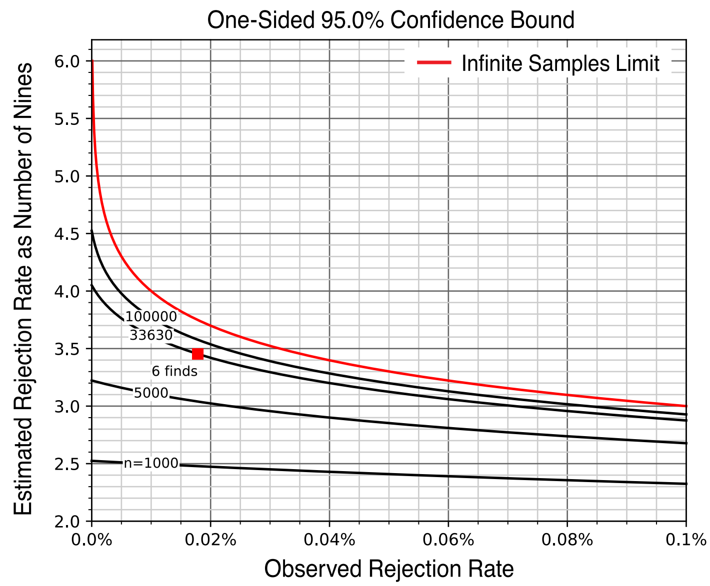


Figure 2
95% confidence upper bound on risk as a function of total inspections and proportion of rejections

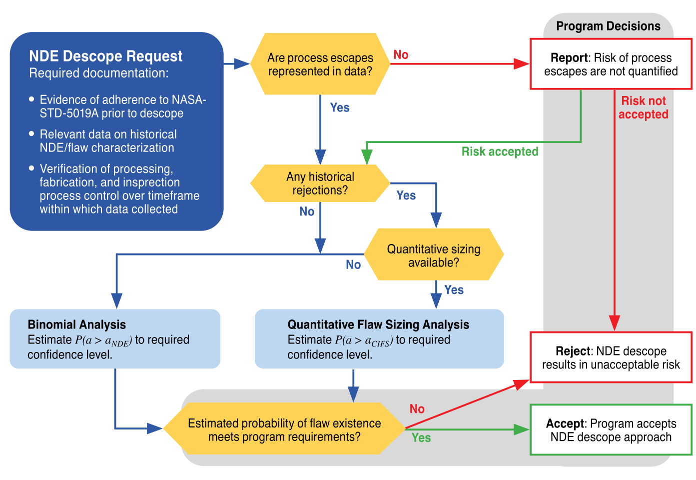


Figure 3
Flowchart of the proposed approach for assessing risk associated with NDE descope

FY25 INNOVATIVE TECHNIQUES

Efficient Large Displacement/Large Rotation Dynamic Simulations Using Nonlinear Dynamic Substructures

Utilizing reduced-order dynamic math models (DMM) in linear system-level dynamic analyses is a well-known practice that enables extreme computational efficiencies. But what about nonlinear system dynamics? Reduced-order DMMs have found their way into contact dynamics. The engineer must look no further than the Henkel-Mar pad separation analysis methodology to verify this fact. More sophisticated applications of DMMs in contact dynamics are possible when certain repetitive geometry pattens are present. For example, Figure 1 shows a type of pipe known as a "flexible" pipe used by the subsea industry. This design features four layers of helically wound steel wires that provide the pipe with its stick/slip behavior during bending, thereby enabling a longer fatigue life in harsh ocean environments. With these helically wound armor layers presenting a repetitive contact topology, contact surfaces can be constructed and tracked enabling the friction logic to operate resulting in the friction hysteretic moment-curvature plot provided in Figure 1 (top).

As seen from Figure 1, the pipe was subjected to many bending cycles and executed in essentially a real-time computation. A single bending cycle of the same pipe in full finite element model (FEM) resolution (i.e., no use of DMMs) would require 48 hours of computation on 36 central processing units (CPUs) running in parallel given the very large order of the FEM.

What about utilizing DMMs for computationally efficient nonlinear dynamics involving large displacements and rotations? Before addressing this question, the residual flexibility mixed boundary transformation (RFMB[1]) must be defined. The RFMB coordinate transformation is given as follows:

$$\begin{Bmatrix} x_b \\ x_c \\ x_o \end{Bmatrix} = \begin{bmatrix} I_{bb} & 0 & 0 \\ 0 & I_{cc} & 0 \\ \psi^c_{ob} - g^R_{oc} g^{R\,-1}_{oc} \psi^c_{cb} & g^R_{oc} g^{R\,-1}_{oc} & \phi^N_{ok} - g^R_{oc} g^{R\,-1}_{oc} \phi^N_{ck} \end{bmatrix} \begin{Bmatrix} x_b \\ x_c \\ q_k \end{Bmatrix}$$

The transformation is a mix of the following submatrices: constraint modes (ψ) due to unit displacements on the b-set boundary degrees of freedom (DoFs) that remain fixed during the eigenvalue problem, residual flexibility (g) due to unit forces at the c-set boundary DoFs that remain free during the eigenvalue problem, and a truncated set of normal modes (ϕ)

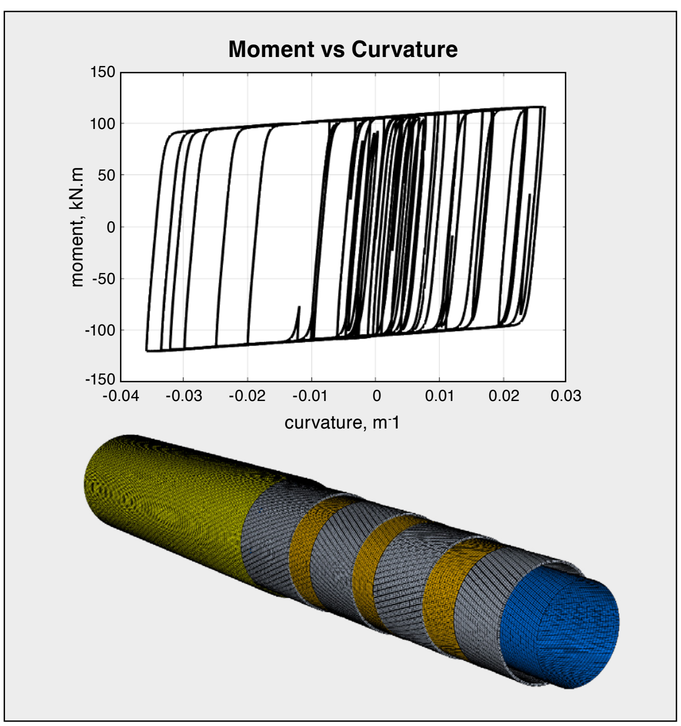


Figure 1. Flexible pipe used in subsea industry; moment-curvature of the flexible pipe using reduced-order dynamic math models for surface contact

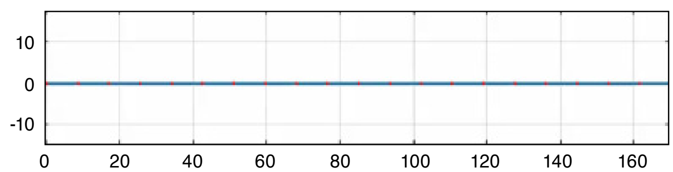


Figure 2. Cantilever beam model composed of 20 DMMs

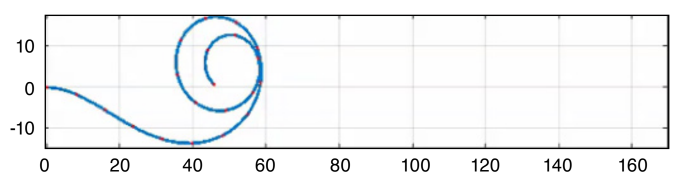


Figure 3. Cantilever beam rolled up using the 20 NDS DMMs

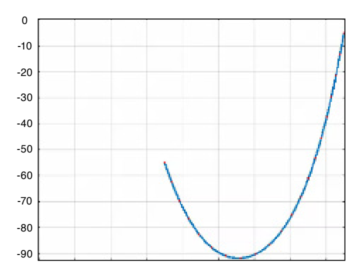


Figure 4. Same beam bent into "catenary-like" configuration by turning on gravity

New and creative engineering approaches developed during NESC technical activities.

computed with the b-set DoFs constrained. It can be shown that the transformation retains full flexibility at the DMM physical DoFs and retains the full dynamics of the FEM up to the user-selected truncation frequency for the normal modes. The reduction of DoFs, and hence the computational efficiency, arises from the number of kept modes (k) being significantly less than the number of interior FEM DoFs.

To enable DMM large displacements/rotations, four coordinates are added to the above RFMB to track large rotations. These quaternions replace the rigid-body modes that are only valid for infinitesimal rotations. With this process, the RFMB is transformed into a nonlinear dynamic substructure (NDS). Solution algorithms need to be modified accordingly as well to allow for equilibrium iterations since the problem now is highly nonlinear. As an example, consider the undeformed cantilever beam model (Figure 2) composed of 20 DMMs (single DMM of a beam composed of 5 CBAR elements repeated 20x).

A moment is applied at the free end (right end) of Figure 2. While small displacement theory is limited and breaks down after a few degrees of rotation, the cantilever beam can be completely rolled up using NDS (see Figure 3) in a highly nonlinear dynamic simulation. Also note that the entire nonlinear dynamic simulation was executed in seconds on a laptop and included all dynamic effects. Similarly, the beam can be bent into a "catenary-like[2]" shape by turning on gravity and enforcing displacements at each end to the required coupling location (see Figure 4).

One application for this large displacement/rotation NDS capability has been to include umbilical models in the coupled loads analysis (CLA) framework. Figure 5 shows the Interim Cryogenic Propulsion Stage (ICPS) umbilical that was integrated into the Space Launch System (SLS) CLA. The SLS CLA is an integrated assembly of various component DMMs (boosters, core stage, mobile launcher (ML), upper stage, etc.) to which the ICPS umbilical (ICPSU) and its hoses as NDS DMMs can now be added. For each hose, one end connects to the SLS vehicle and the other end to the ML structure. As an example, Figure 6 shows the evolution of the deformations of the forward vent hose (modeled with 20 NDS DMMs) as it goes from the undeformed geometry (straight line) into its prelaunch geometry during the initial condition setup in the CLA.

As the timed command for umbilical separation is given, the vehicle-side ground plate separates (using the Henkel-Mar contact/separation algorithm) and the ML gantry rotates the separating umbilical away from the already lifting vehicle (the gantry was brought into the CLA as a NDS capable of large rotations). Figure 7 captures the post-separation forward vent hose dynamics (extracted from the CLA). From this, 100 ICPSU hose clearances to the lifting vehicle can be computed.

The power of the reduced-order models does not end with linear dynamics. It is possible to introduce large displacements and rotations into reduced-order models to enable seamless integration into large substructured integrated system dynamic analyses such as a CLA. For the specific case of the SLS, this capability allowed us to integrate umbilicals into the CLA to more accurately capture the impact of system flexibilities, dynamic response to forcing functions, pad separation "twang" effects, ML dynamics, and gantry/umbilical timings on clearances. ●

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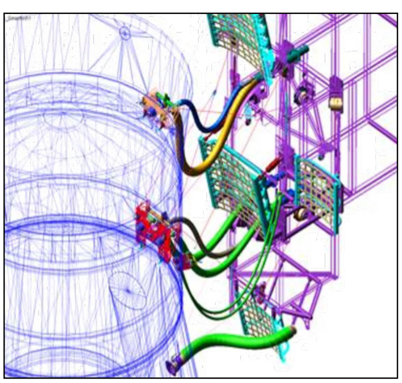

Figure 5. ICPSU model integrated into the SLS CLA

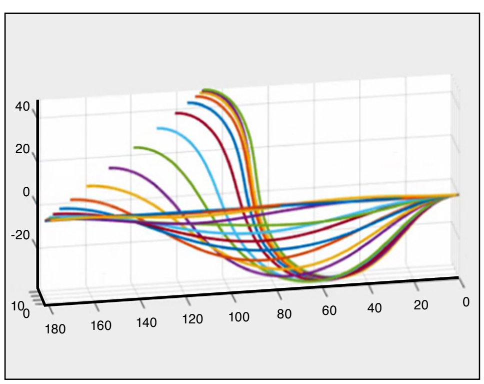

Figure 6. ICPSU forward vent hose evolution of deformations from undeformed (straight line) to prelaunch configuration (locking in preloads) during the CLA initial conditions setup (extracted from the CLA)

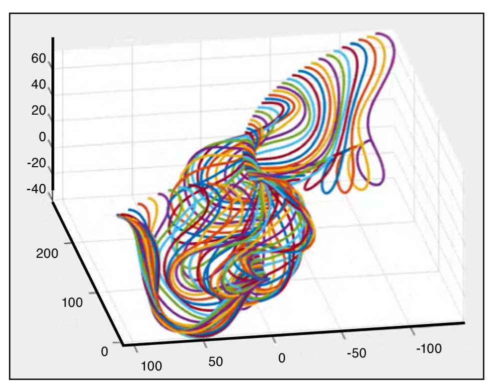

Figure 7. Forward vent hose post-separation dynamics (extracted from the CLA)

[1] Developed by A. Majed and E. E. Henkel of ASD, Inc. RFMB is the default dynamic reduction method in MSC/NASTRAN. [2] Typical catenary does not include bending stiffness; it is more like a chain structure. This model includes bending stiffness, which is a key and important distinction when it comes to modeling umbilical hoses for example.

FY25 INNOVATIVE TECHNIQUES

Insights into Spallation Mechanisms of Thermal Protection System Materials from Mass Spectrometry and HyMETS Testing

An effort was undertaken to investigate the mechanisms responsible for internal pressure build up within thermal protection system (TPS) materials subjected to high-enthalpy environments. Understanding how gases evolve, migrate, and interact with the microstructure of a TPS is essential for predicting degradation and failure modes such as spallation. To this end, complementary experimental approaches were employed that provided both chemical and mechanical insight into subsurface processes.

Chemical evolution and internal pressure buildup were identified using the processes illustrated in Figure 1. In part A, in-depth pressure measurements obtained during testing in the Hypersonic Materials Environmental Test System (HyMETS) quantified the dynamic buildup of subsurface pressure as gases evolved. In part B, mass spectrometry was applied to characterize volatile species released as the TPS decomposed under heating. This analysis distinguished between species that desorb at lower temperatures, such as water release prior to significant changes in permeability, and those produced during the breakdown of the polymer backbone through high-temperature pyrolysis. Together, these data sets established a quantitative link between chemical decomposition and mechanical response, forming a foundation for interpreting how microscale chemical processes manifest as macroscale material instability.

Lessons gleaned from mass spectrometry and HyMETS testing led to an enhanced understanding of the spallation mechanisms of TPS, as illustrated in Figure 1. Initial heating of the TPS induces the release of absorbed water from microballoons and the surrounding matrix before extensive pyrolysis (I). This early release of exiguous water can generate localized stresses when the material is in a state of low permeability and may result in localized crack formation before pyrolysis. As heating continues, the pyrolysis front advances, liberating a significant amount of gas and a rapid buildup of pressure occurs (II). If the internal pressure surpasses the local material strength, sudden ejection of fragments follows, marking a spallation event (III). This sequence highlights the probable interplay between early-stage volatile release, pyrolysis gas evolution, and stress generation, all of which govern the stability of TPS material under entry conditions. ●

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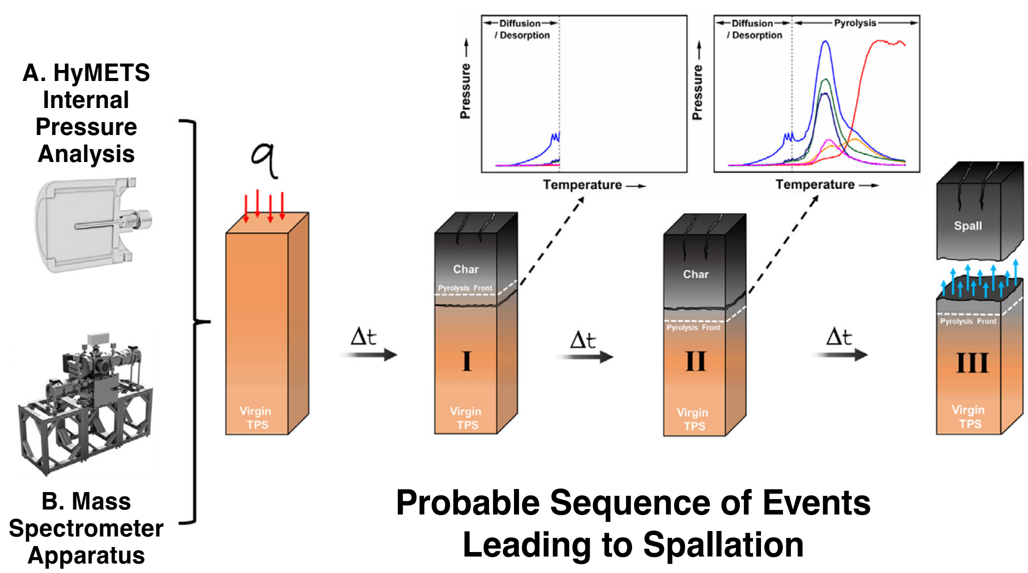


Figure 1. Probable sequence of events leading to spallation in TPS. Early water release from microballoons and pre-cracking (I), followed by pyrolysis gas evolution (II), and pressure-induced spallation (III). The blue trace corresponds to water released in limited amounts during thermal desorption and larger quantities during pyrolysis. The remaining curves represent various low and high molecular weight species generated during pyrolysis.

New and creative engineering approaches developed during NESC technical activities.

Computational Modeling of Failure at the Fabric Weave Level in Reentry Parachute Energy Modulators

Energy modulators (EM) are textile mechanical devices designed to dissipate snatch loads that occur when parachutes are deployed. Although critical for mitigating shock loads, recent flight testing has shown increasing variability in EM behavior, raising concerns about their performance predictability and potential failure under dynamic loading conditions. In response, a novel approach was implemented to create a computational model of an EM at the fabric weave level using the simulation software, LS-DYNA. This work was organized into two primary objectives: (1) development of a per-unit stitch model capturing the geometry and material behavior of the EM stitching pattern, and (2) implementation of a Python script to duplicate the unit model along the full length of an EM ear, simplifying the process of generating complex, patterned geometries in LS-DYNA.

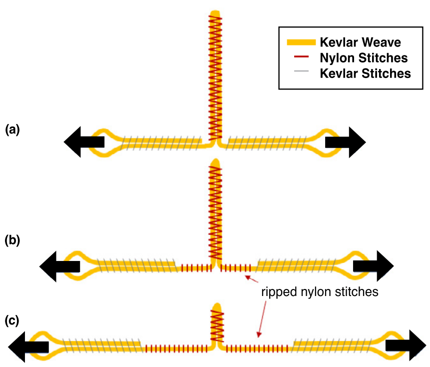
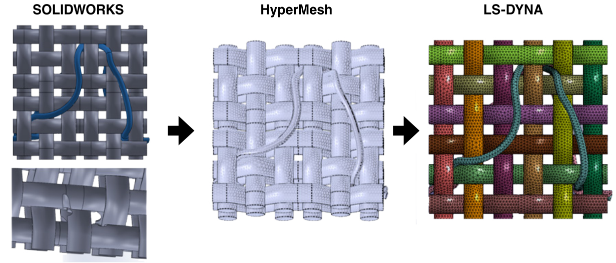


Figure 1: Depiction of EM extension during stroking from a tensile force applied at the blue arrows with (a) an unextended EM, (b) a partially extended EM, and (c) a fully extended EM

EMs typically consist of a long strip of structural Kevlar webbing that is folded and stitched together with a nylon zigzag stitching pattern to form an EM "ear." As an EM is pulled above a threshold load during deployment, the nylon stitching rips, unfolding the EM and dissipating shock forces. This process is illustrated in Figure 1, exemplifying stages of EM extension during stroking. In nominal cases, the EM cleanly tears with little damage to the Kevlar webbing. However, anomalous cases have been observed where the nylon stitches along the ear are skipped during loading, i.e., when a row of stitches do not tear in sequence. This results in failure of the surrounding Kevlar webbing, referred to as EM shredding. The inherent unpredictability of the fabric behavior and the high variability of flight loading conditions make a root cause challenging to identify through mechanical testing.

In this study, development of a computational model of an EM in LS-DYNA was used to gain deeper insight into the cause of EM shredding. While similar studies of fabric webbing have modeled fabrics at a global level, this approach represents each thread of the Kevlar weave and nylon stitching as individually modeled 3D solid elements. Modeling each thread individually within the weave is essential not only for analyzing the failure mechanisms of the nylon stitching as it rips, but also for understanding the Kevlar weave failure during the EM shredding events.

The first phase of this work focused on modeling individual Kevlar and nylon threads within a representative stitch geometry. A 3D model of the Kevlar weave was first generated using TexGen, an open-source software developed at the University of Nottingham. Using computer-aided design (CAD) software, nylon stitching passing through two layers of the Kevlar fabric weave was added. The nylon stitching pattern consisted of a bobbin thread and a needle thread that looped through the top and bottom layers, respectively, of the Kevlar weave pattern and twisted together at the end of every stitch between the two layers. The unit model was meshed in Hypermesh with 3D tetrahedral solid elements.



In LS-DYNA, the material properties, contact, failure conditions, and boundary conditions were defined to assess the dynamic response of a stitch during tensile loading. Material behavior for both fabric types was defined using *MAT_ELASTIC (*MAT_001), and two-way, surface-to-surface contact with erosion was implemented to capture progressive failure of the Kevlar weave and nylon threads. Boundary conditions were applied to replicate in-flight tensile loading scenarios. Additionally, several case studies were conducted to reduce computation time, including manual mass scaling, characteristic length analysis, and mesh quality optimization.

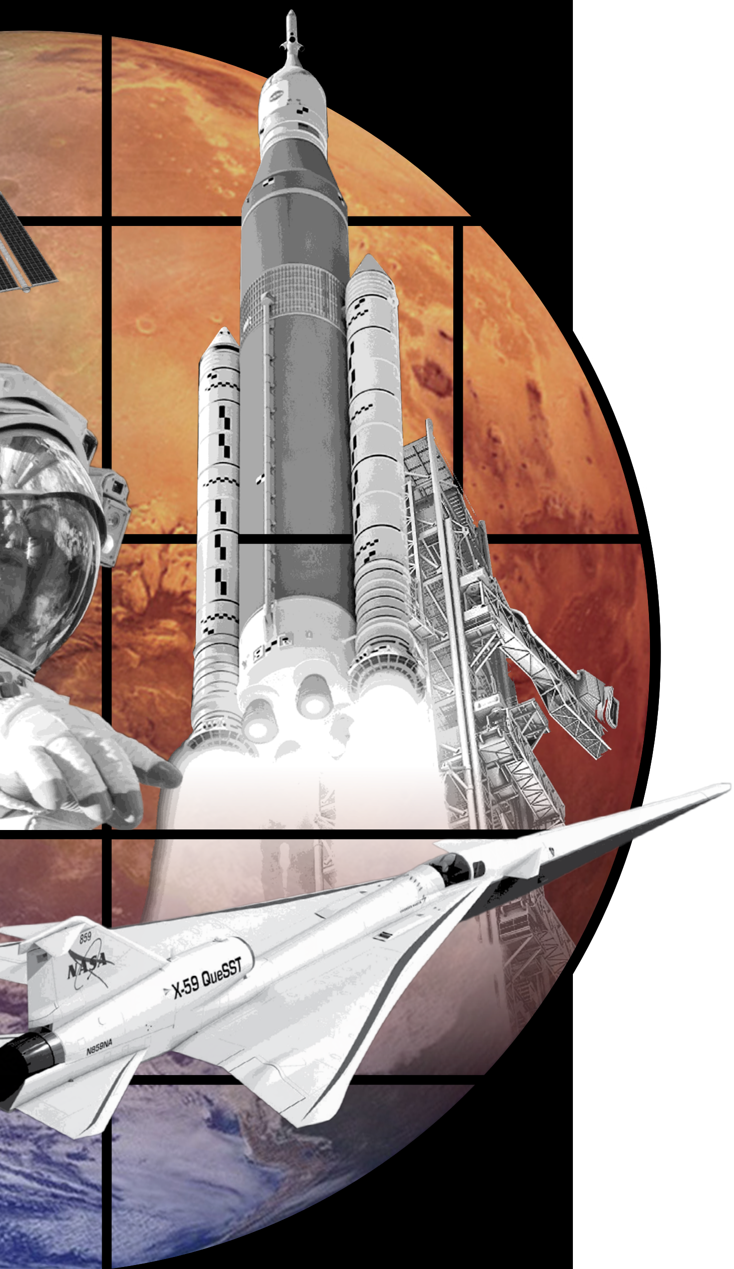
Preliminary results from the EM per-unit model validated the use of solid elements to capture EM behavior, particularly the interaction between Kevlar and nylon threads. To streamline the construction of full-length EM models, the second phase of this work focused on developing a Python script to replicate the per-unit LS-DYNA model along the length of an EM ear. This eliminated the need for large CAD assemblies by generating the full model directly from duplicating the unit model. This model is applicable to both solid and shell 2D and 3D elements. Overall, these results will not only aid in identifying the root cause of EM shredding but also support the evaluation of new EM design variations. This modeling approach has broader implications for other work involving fabrics, enabling more accurate simulations and efficient design workflows in aerospace textile applications. ●

For information, contact Annika M. Vaidyanathan, Alexander Chin, John Bell, and Rumaasha Maasha.

DISCIPLINE FOCUS

DISCIPLINE PERSPECTIVES RELATED TO NESC TECHNICAL ACTIVITIES

Each year the NESC engages in assessments that not only benefit its stakeholders, but contribute to the advancement of NASA's many technical disciplines. In 2025, some of these assessments helped shape and influence the future of spaceflight in the areas of human factors, thermal control & protection, structures, and nondestructive evaluation.



A network of over 1,100 engineers and scientists across the 20 disciplines listed below are available to help with NESC assessments.

- Aerosciences
- Avionics
- Cryogenics
- Electrical Power
- Environmental Control & Life Support
- Flight Mechanics
- Guidance, Navigation, & Control
- Human Factors
- Loads & Dynamics
- Materials
- Mechanical Systems
- Nondestructive Evaluation
- Nuclear Power & Propulsion
- Propulsion
- Sensors & Instrumentation
- Software
- Space Environments
- Structures
- Systems Engineering
- Thermal Control & Protection

HUMAN FACTORS

Dr. Cynthia H. Null
NASA Technical Fellow for Human Factors

Expanding the Human Factors Toolbox:

An Approach to Balancing Crew and Mission Design Parameters

The human factors TDT looks for and creates opportunities to influence design to leverage human strengths and to protect people and missions. The human factors team has experts with knowledge of human performance in all aspects of NASA missions as well as from other safety-critical industries. The goal is to ensure that science-based human factors knowledge and lessons learned are applied throughout the mission lifecycle. The strategy is to 1) modify existing and create new discipline tools that meet NASA's needs and constraints, 2) build strategies to enhance the disciplines' chances for success, 3) enhance simulation techniques to gain maximum information even when verification and validation opportunities are limited, 4) develop new analysis methods for human performance in NASA mission contexts, and 5) reframe understanding of human performance to emphasize the key role of human resilience in mission success.

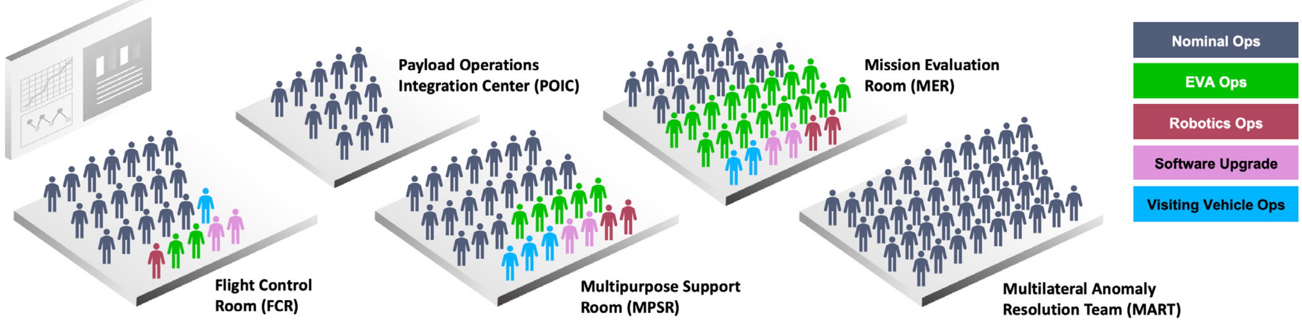
This article highlights a set of analytical models of crew workload, training, and expertise that can be used to aid decision makers in determining the size of a Mars crew adequate for crew safety and mission success. These tools are built on a Department of Defense (DoD) capability that has been used extensively to evaluate the success of specific designs. Unlike missions in low Earth orbit or even to the Moon, a crewed Mars mission will operate under extraordinary constraints, primarily a significant communication delay with Earth and prolonged communication blackout periods. This necessitates a radical rethinking of mission design, including the human elements of crew size, workload, expertise, and resilient performance.

To address this gap, the NESC developed a systematic and quantitative methodology, along with an associated suite of modeling tools, to enable the development of an evidence-based trade space for guiding crew size decisions for human Mars missions. This work provides actionable analysis to programs and projects early in development, enabling simultaneous consideration of mission architecture, operational concepts, and the roles human will play throughout the mission. This analysis supports the development of mission designs that preserve and enable human resilient performance to ensure the success and safety of future Mars exploration.

Historically, NASA's human spaceflight programs have relied on real-time support from extensive ground control, composed of a collective intellect that acts as an extended crew to manage objectives and respond to anomalies. As depicted in Figure 1, the volume of ISS ground personnel highlights the vast support structure available for Earth-proximal missions. However, for Mars, communication delays of up to 22 minutes one-way and blackouts lasting up to three weeks during superior conjunctions will eliminate this real-time lifeline. This demands a new focus on the capabilities required of the onboard crew, who will face time-critical decisions and unforeseen failures with only their knowledge and onboard decision-support systems, often without pre-existing procedures.

The NESC's methodology fills a longstanding gap, as past Mars crew size determinations often lacked detailed quantitative analysis of crew tasking, workload, and expertise. Extending DoD methodologies for manpower determination, the NESC human factors trade space methodology offers a repeatable and data-driven means to assess whether a given crew complement possesses the capability to accomplish mission objectives and respond successfully to unforeseen failures that have potential loss of crew or loss of mission (LOC/LOM) consequences. The core process involves gathering Mars mission concepts and information, determining use cases to model, creating a trade space evaluation

MEASURING THE GAP:
Current Ground-Support Expertise that Would be Unavailable for Real-Time Support to a Mars Crew



The enormous amount of experience and expertise on the ground during ISS missions is distributed among several teams. In the MIssion Control Center (MCC) front and back rooms (FCR + MPSR) there are 50+ operators on console and 20+ specialists on call. Operators possess ~500 years combined on-console experience and 600+ years combined relevant experience. In the MER there are 30+ engineers on console with ~161 years combined on-console experience and 556 years combined relevant experience (estimated based on average experience level of MART participants.) **Reference:** Panontin, T. L., Wu, S. C., Parisi, M. E., McTigue, K. R., & Vera, A. H. (2021) *Human-Systems Integration Architecture Needs Analysis: On-Board Anomaly Resolution During Autonomous Operations*. NASA's Human Research Program Technical Report https://ntrs.nasa.gov/citations/20250001469

Figure 1. Current ground-support expertise for ISS missions

framework, conducting human performance modeling, and performing trade space analyses. This iterative approach, conceptually represented by the Mars Crew Size Decision Process (see Figure 2), allows for adaptation as technologies and mission assumptions evolve.

Central to this methodology are four human performance models, each revealing critical insights into the human factors of Mars mission design.

1. IV Operations for Planetary Surface EVA Model: This model examined the mental workload of intravehicular (IV) Mars crewmembers supporting a planetary surface extravehicular activity (EVA), simulating activities currently performed by Mission Control Center personnel for ISS EVAs. It predicted that during a Mars surface technical EVA conducted at the pace of an ISS EVA, the workload for an IV crewmember performing combined essential flight controller duties would be unacceptably high, indicating a severe negative impact on task performance. This finding underscores the necessity of reconsidering EVA pacing, task automation, or increasing IV support crew complement to ensure mission-critical EVAs are safely conducted independently of Earth-based support.

2. Robotic Arm Assisted EVA Operator Model: This model assessed the mental workload of a crewmember operating a robotic arm (see Figure 3) in both manual and automated control modes on a Mars transit vehicle. The model results indicate that two crewmembers may be necessary to mitigate unacceptably high workload during manual robotic arm operations. Furthermore, consistent with the scientific literature, the model predicted that stressors like sleep debt increase mental workload and degrade performance, extending task completion times. This highlights the importance of accounting for crew well-being in crew-size determinations.

3. Mars Transit Crew Model: This analysis focused on crew utilization and staffing requirements during a 9-month Mars transit mission, reallocating planned and unplanned tasks from ground control to the crew. The modeling, using ISS-equivalent task assumptions, predicted that more than six crewmembers (given average rates for unplanned events) would be needed to achieve the same number of work hours as a four-person ISS mission. This substantial increase emphasizes the critical impact of Earth-independence on daily crew workload and the imperative for adequate crew complement to manage ongoing responsibilities.

4. Personnel, Expertise, and Training Model: Given the communication delay/blackout with Mars, paired with no rapid return-to-Earth options, NASA will need to rely on the expertise of the crew to respond to unforeseen failures. A custom model was developed to quantify the crew expertise required to meet mission objectives and respond to unforeseen events with LOC/LOM potential and short time-to-effect. Based on analysis of ISS historical data, the probability of at least one occurrence of such a failure during Mars transit is greater than 99%. A sensitivity analysis of the relationship between a successful crew response and LOC/LOM outcome was conducted for cases in which the crew gave a successful response 90%, 95%, 98%, and 99.985% of the time. The estimated likelihood of a LOC/LOM consequence for all but the most conservative of these cases is greater than 1%, which is considered in the "very high" (red) range, per the Human System Risk Board risk matrix. The likelihood of LOC/LOM consequences only drops below 0.1% (yellow) for a successful response rate of 99.985%. When unforeseen failures occur on a mission to Mars, it will be critical that the crew have the necessary level of expertise to accurately diagnose problems and restore critical functionality. The Personnel, Expertise, and Training model is designed to provide the agency with the capability to consider the trade space of crew size and level of expertise in the real-time environment, where the in-mission expertise is a necessary component for mitigating high-consequence risks.

The next phase of this assessment is continuing in FY26 and aims to support the Moon to Mars Program Office's critical decisions on crew complement for both Mars vicinity and surface mission crews. It will achieve this by updating the IV Operations for Contingency EVAs model, improving the Personnel, Expertise, and Training model, and integrating these results into a new model for Mars vicinity operations to quantitatively analyze crew workload, expertise, and task reallocation for Earth-independent operations.

Rather than prescribing a definitive crew size, the NESC's human factors methodology provides a robust, data-driven framework for evaluating the complex trade space between crew size and mission architecture. It underscores that the optimal crew size for Mars exploration is not a fixed number, but a strategic, data-informed decision—one that must be grounded in rigorous analysis and a deep understanding of the human challenges inherent to long-duration spaceflight. ●

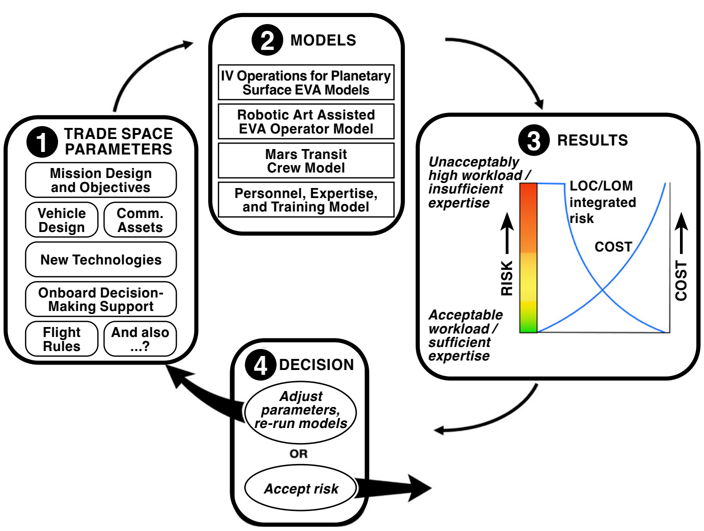


Figure 2. The NESC's proposed methodology to aid crew-size determinations. Trade-space parameters are input into any of four models, whose output characterizes the risk level associated with a given crew size.

Figure 3. Astronaut Anne McClain using the Space Station Remote Manipulator System on ISS.

STRUCTURES and NONDESTRUCTIVE EVALUATION

Heather K. Hickman
Associate NESC Principal Engineer

COPV Damage Tolerance Life Demonstration Guidelines

The NESC has invested significant time and resources to better understand composite overwrapped pressure vessels (COPV) performance and more importantly, how these complex, high-pressure storage systems can fail. These vessels, which store high pressure propulsion and life-support system fluids on launch vehicles and spacecraft, are ubiquitous at NASA, and failures have the potential to be catastrophic.

This year the NESC finalized work on a set of guidelines intended for use by NASA civil servants and support contractors in their development or assessment of damage-tolerance demonstration data for COPVs. These guidelines are based on the NESC's experience in assessing agency-wide COPV applications and compiling the best practices for complying with the damage-tolerance requirements of AIAA S-081, the standard for COPVs used in human and robotic spaceflight, and NASA-STD-5019, *Fracture Control Requirements for Spaceflight Hardware*.

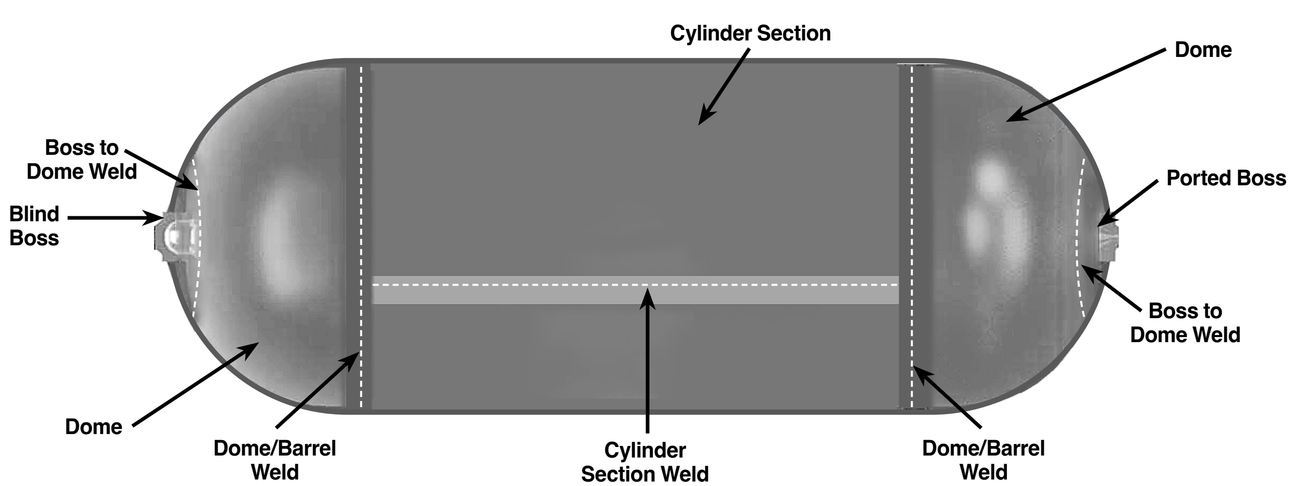
Previously referred to as "safe-life," damage tolerance life assumes detectable cracks exist before service and demonstrates that such cracks, in worst-case locations and orientations, will not grow to failure over the service life. A 4x life factor is applied, requiring that cracks do not reach failure (leakage or unstable growth) within four times the expected service cycles.

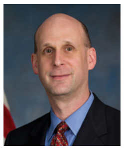
These guidelines are meant to support NASA personnel in applying S-081 requirements and also to clarify areas that historically have had varied interpretation. And by leveraging NESC assessments where approaches to damage tolerance were found to be unconservative, the guidelines offer best practices for minimizing risk based on supporting data—and do so without introducing new standards. The guidelines touch on numerous aspects of damage tolerance life including:

- COPV mechanics and model correlation,
- Identifying worst case locations for damage tolerance,
- Nondestructive evaluation (NDE),
- Addressing crack aspect ratios,
- Defining load spectra,
- Addressing autofrettage crack growth,
- Performing damage-tolerance life demonstration by analysis using a crack-growth analysis software like NASGRO,
- Performing damage-tolerance life by coupon or vessel testing, and
- Addressing sustained-load crack growth and environmentally assisted cracking.

In determining the worst-case locations for damage tolerance evaluation, the guidelines offer a method for evaluating the contributing factors—stress/strain, material properties, thickness, and initial crack size. The identified regions show different liner material forms and welds, and within each form, the initial crack size based on the NDE method used, the minimum thickness, and the peak stress/strain level are determined for that form. The guidelines then provide best practices for addressing damage tolerance with each material form and worst-case location in the COPV. ●

EXAMPLES OF MATERIAL FORMS IN COPV LINER





THERMAL CONTROL & PROTECTION

Steven L. Rickman
NASA Technical Fellow for Thermal Control & Protection

A Technical Resource for the Agency

The NESC's Thermal Control & Protection Technical Discipline Team (TDT) is a resource providing subject matter expertise in active and passive thermal control as well as ascent and entry thermal protection across the spectrum of agency needs. TDT members led or supported a variety of key activities including the ongoing Artemis I heat shield char loss investigation, assessing viable thermal control fluids as replacements for those being phased out due to Per- and Polyfluoroalkyl Substances (PFAS), conducting Commercial Crew-related thermal control and thermal protection analysis peer reviews, and leading and providing expertise to the Dragonfly Thermal Advisory Board and the Nancy Grace Roman Space Telescope Standing Review Board.

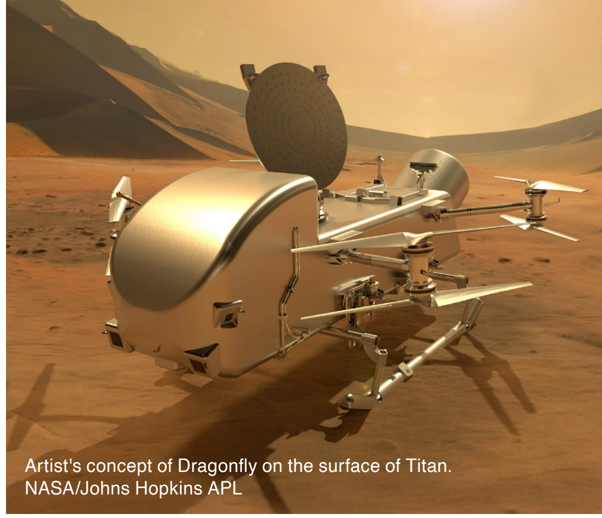
Enhancing the Thermal Community of Practice

The TDT welcomed two new early-career engineers for a one-year rotation after the program's successful inaugural year. This experience helps to train the next generation of engineers and leaders. Rotational engineers are responsible for formulating the TDT's annual State of the Discipline presentation, an assessment of the overall health and needs of the thermal control and thermal protection disciplines. Additionally, the rotational engineers may be involved in a variety of other TDT activities including initial work on a thermal control standard and maintaining the thermal control and protection critical technologies list to broaden their experience and to become familiar with key thermal work across the agency.

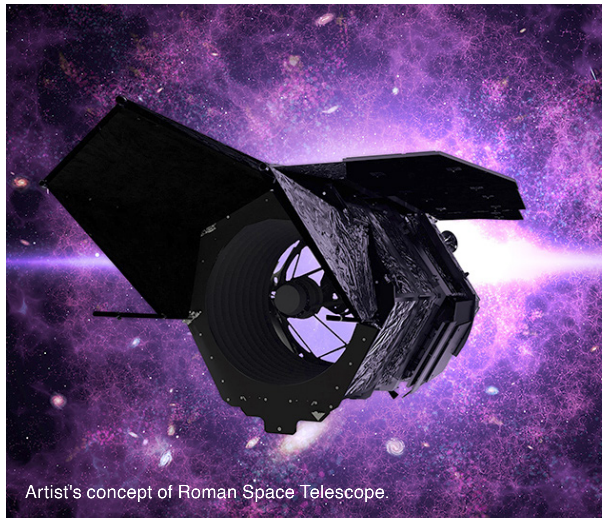
The TDT continued to embrace its responsibility to maintain and enhance the thermal control and protection community of practice through presentation of three webinars covering file plotting tools, two-phase flow, and Dragonfly thermal design. The TDT also developed a lesson on thermal louvers for inclusion into the NESC Academy.

The TDT remains the lead cosponsor of the Thermal and Fluids Analysis Workshop (the other cosponsors are the Aerosciences and Cryogenics TDTs), an annual, longstanding NASA-owned event that provides training and is designed to encourage knowledge sharing, professional development, and networking throughout the NASA thermal and fluids engineering community and the aerospace community at large. The workshop features technical sessions and presentations, analysis software demonstrations and training, technical short courses, a student poster session, guest speakers, and speed mentoring. This year's event was planned and presented by the Ames Research Center in partnership with San Jose State University and drew nearly 350 attendees. The NASA Technical Fellow for Thermal Control & Protection presented a theory-based short course titled "Introduction to Orbital Mechanics and Spacecraft Attitudes for Thermal Engineers." The vision of TFAWS is to maintain continuity over time and between disciplines throughout the thermal and fluids engineering community.

To inspire the next generation of engineers, the Technical Fellow also provided lectures and guidance to students at the Rice University Aerospace Academy reaching more than 300 students in the grades 9 through 12. ●



Artist's concept of Dragonfly on the surface of Titan.
NASA/Johns Hopkins APL



Artist's concept of Roman Space Telescope.

TFAWS attendees participating in one of the technical sessions offered during the workshop.

TFAWS attendees interact with students during the poster session event.

NESC HONOR AWARDS

Recognizing those who have made outstanding contributions to the NESC mission, demonstrate engineering and technical excellence, and foster an open environment.

Awarded annually to NASA employees, industry representatives, and other stakeholders for their efforts and achievements in engineering, leadership, teamwork, and communication.

NESC LEADERSHIP AWARD

Lianne M. Kuster

In recognition of sustained and outstanding leadership of the NESC's Orion Crew Module Heat Shield Avcoat Char Investigation Fault Tree Subteam.

Stephen E. Cutright

In recognition of exemplary leadership of the NESC’s Parachute Energy Modulator and Parachute Extraction Qualification Testing for the Commercial Crew Program.

NESC ENGINEERING EXCELLENCE AWARD

Robert L. Harris

In recognition of engineering excellence and tireless dedication to the success of the Commercial Crew Program's parachute testing to ensure the safe return of astronauts and cargo from the International Space Station.

Jonathan A. Bentley

In recognition of engineering excellence in modeling a commercial crew provider’s helium pressurization system, validating models with flight data, and supporting critical decisions.

James C. Buzzell

In recognition of engineering excellence and technical leadership sustained over multiple years enabling rapid data-driven response to anomalies before and during the Crew Flight Test mission.

Brody K. Bessire
In recognition of engineering excellence for evaluation of gas generation in thermal protection system material in support of the Orion Heat Shield Char Loss Investigation.

Marcus A. Lobbia
In recognition of engineering excellence in implementing a new Pacific Coast landing capability and urgent certifications to reduce risk during reentry for the Commercial Crew Program.

Justin R. McFatter
In recognition of engineering excellence and technical mechanical system expertise employed to address technical issues for multiple NESC Artemis assessments.

Adam T. Sidor
In recognition of engineering excellence for evaluation of thermal protection system material constituents and integrated performance, which provided crucial insights for the Orion Heat Shield Char Loss Investigation.

Elizabeth J. Young-Dohe
In recognition of engineering excellence and outstanding forensic investigation in support of the NESC's Spacecraft Thruster Assessment.

NESC GROUP ACHIEVEMENT AWARD

NESC ISS PrK Anomaly Investigation Assessment Team
For outstanding testing and forensic investigation in support of the NESC assessment into the ISS Russian PrK Module.

NESC Orion Crew Module Heat Shield Avcoat Char Investigation Team
In recognition of outstanding technical excellence in the investigation of the Orion heat shield char loss to ensure the safety and success of future Artemis missions.

NESC Parachute Extraction System Test Team
In recognition of outstanding technical achievement in developing and executing critical tests to qualify parachute systems ensuring the safety of crew and cargo missions for the Commercial Crew Program.

NESC SX50 Pressure Sensor Anomaly Assessment Team
In recognition of engineering excellence for testing and determining root cause of a flight combustion chamber sensor unexplained flight anomaly.

NESC Exploration Systems Exterior Lighting Design Guidance Assessment Team
In recognition of exceptional technical achievement in assessing complex challenges affecting human vision related to direct lighting and reflection effects on the lunar surface.

NESC Trade Space Analysis Assessment Team
In recognition of significant technical development of a quantitative tool to support evidence-based trade-space decisions on crew size for human Mars missions.

NESC Tape Flammability Test Team
In recognition of outstanding engineering excellence in the development of an innovative test approach to inform the fire safety risk of P213 tape in a Commercial Crew Program provider’s vehicle.

NESC Fire Suppression Test Team
In recognition of exceptional flexibility, speed, and technical rigor in support of an NESC assessment evaluating Commercial Crew Program fire safety systems.

NESC Spacesuit Glove Standard Development Team
In recognition of exceptional technical rigor in developing standardized spacesuit glove test methods and for trailblazing the inclusion of NASA spacesuit standards in the American Society for Testing and Materials.

NESC LEA

OFFICE OF THE DIRECTOR


NESC Director
Timmy R. Wilson


NESC Deputy Director
Michael T. Kirsch

NIO Manager
Vacant


MTSO Manager
Lisa A. McAlhaney


NESC Technical Leader for Safety
Peter Panetta


NESC Chief Astronaut
Mark T. Vande Hei

NESC PRINCIPAL ENGINEERS

Manage/lead cross-discipline NESC technical activities and provide technical and project management guidance and assistance to assessment teams.


Gregory J. Harrigan


Donald S. Parker


Michael D. Squire

Vacant

NESC CHIEF ENGINEERS

Liaison between respective resident NASA centers and the NESC. Foster proactive involvement with the programs/projects and provide technical expertise and resources to resolve issues.

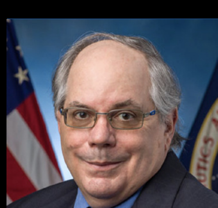

Ames
Dr. Donald R. Mendoza

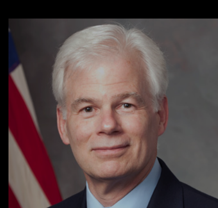

Armstrong
Sean Clarke


Glenn
Robert S. Jankovsky


Goddard
Carmel A. Conaty


JPL
Kimberly A. Simpson


Johnson
Joel W. Sills


Kennedy
Stephen A. Minute

Langley
Vacant

Marshall
Vacant

Stennis
Vacant

Full Bios at **nasa.gov/nesc**

(as of September 30, 2025)

ADERSHIP

NASA TECHNICAL FELLOWS

Senior-level engineers and scientists with distinguished and sustained records of technical achievement. Considered leading experts in their respective technical disciplines. They assemble and provide leadership for the Technical Discipline Teams and as such they sponsor discipline-enhancing activities and educate the agency.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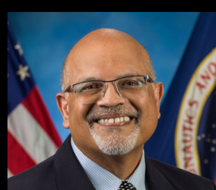
Avionics
George L. Jackson

Cryogenics
Vacant

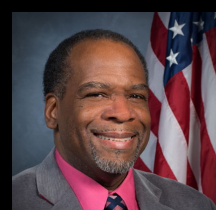
Electrical Power
Vacant


Environmental Control & Life Support
Dr. Morgan B. Abney


Flight Mechanics
Heather M. Koehler


GNC
Dr. Christopher N. D'Souza


Human Factors
Dr. Cynthia H. Null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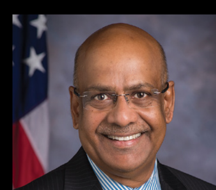
Materials
Dr. Bryan W. McEnerney


Mechanical Systems
Dr. Michael J. Dube

Nondestructive Evaluation
Vacant


Propulsion
Dr. Jonathan E. Jones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Software
Vacant


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Dr. Joseph I. Minow


Structures
Deneen M. Taylor


Systems Engineering
Jon B. Holladay


Thermal Control & Protection
Steven L. Rickman

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Christopher S. Creely, Office of Safety and Mission Assurance (OSMA)

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DR. DANIEL WINTERHALTER
NESC Chief Scientist (2005-20)

MARY ELIZABETH WUSK
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NIO Manager (2022-25)

PUBLICATONS

BASED ON NESC ACTIVITIES

Technical Papers, Conference Proceedings, and Technical Presentations

AVIONICS

1. Hodson, R. F. (2025, March 11–12). Engineering @ NASA with a slant towards avionics [Student presentation]. Engineering Student Presentation, Orlando, FL, United States.
2. Jackson, G. L., & Chen, Y. (2025, April 30). 22-01873 Cold electronics report. Presented at the Lunar Cold Electronics Technical Assessment Meeting (April 30–May 1, 2025), NASA, Pasadena, CA, United States.
3. Hodson, R. F. (2025, August 11–14). The only constant is change [Conference presentation]. 16th Annual NASA Electronic Parts and Packaging (NEPP) Program's Electronics Technology Workshop (ETW), Greenbelt, MD, United States.
4. Jackson, G. L., Chen, Y., & Some, R. (2025, August 11–14). NESC assessment on cold electronics for lunar mission [Conference presentation]. 16th Annual NASA Electronic Parts and Packaging (NEPP) Program's Electronics Technology Workshop (ETW), Greenbelt, MD, United States.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT

1. Abney, M. B. (2024, November 13). ChemE's on the job: Solving Artemis challenges [Invited talk]. University of Kentucky Professions Class Briefing, University of Kentucky, Lexington, KY, United States.
2. Abney, M. B., Brady, T., Morris, D., Wilson, S., Andersen, N., Conger, B., Jones, R. J., McFarland, S., Smith, W., Shiraishi, L., Deaton, A. S., & Funk, A. (2025, July 13–17). Establishing a standardized test method for evaluating spacesuit gloves thermal performance at lunar South Pole temperatures (ICES-2025-64). 54th International Conference on Environmental Systems, Prague, Czech Republic.
3. Burke, R., Deans, E., Jones, R. J., Morris, D., Abney, M. B., Deaton, A. S., Andersen, N., Conger, B., & McFarland, S. (2025, July 13–17). Development and validation of a novel instrumented thermal hand manikin for the evaluation of lunar gloves (ICES-2025-412). 54th International Conference on Environmental Systems, Prague, Czech Republic.
4. Abney, M. B., Nalette, T., Wickham, D., Engel, J., Spilker, C., Castanuela, G., Reichert, R., Barrett, L., & Williams, D. (2025, July 13–17). Investigation of ISS fire cartridge catalyst deactivation (ICES-2025-75). 54th International Conference on Environmental Systems, Prague, Czech Republic.

FLIGHT MECHANICS

1. Hawkins, M. (2025, January 19–23). Check-cases for lunar six-degree-of-freedom (6DOF) simulations [Conference presentation]. 2025 AAS/AIAA Space Flight Mechanics Meeting, Kaua'i, HI, United States.

GUIDANCE, NAVIGATION, AND CONTROL

1. Fleck, J. R., VanZwieten Cook, T., Davidson, J., Bertaska, I., Shidner, J., & Hall, C. (2025, January 31–February 5). Independent verification and validation of Artemis I ascent integrated flight performance simulations (AAS 25-128). 47th Annual American Astronautical Society (AAS) Guidance, Navigation and Control (GNC) Conference, Breckenridge, CO, United States.
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4. D'Souza, C., Shankar, U., & Dennehy, C. (2025, January 31–February 5). The NASA Jitter Handbook development activity: A multidisciplinary collaborative effort [Conference presentation]. 47th Annual American Astronautical Society (AAS) Guidance, Navigation and Control Conference, Breckenridge, CO, United States.
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6. Wall, J., & VanZwieten Cook, T. (2025, July 7–10). V and V of adaptive augmenting control system flown on NASA's Space Launch System for Artemis. Inter-Agency GNC Verification and Validation Workshop, Toulouse, France.

HUMAN FACTORS

1. Null, C. (2025, April 24–25). Lunar South Pole light, human vision, and simulation. LAMP-Rover Workshop, Moffett Field, CA, United States.

LOADS AND DYNAMICS

1. Kabe, A. M. (2025, May 1). Fluid slosh and azimuthal rotation. Presentation at the NESC Structural Dynamics Technical Discipline Team Face-to-Face Meeting, NASA Kennedy Space Center.
2. Kabe, A. M. (2025, May 1). Coupled loads analysis forcing functions – Part II-B. Presentation at the NESC Structural Dynamics Technical Discipline Team Face-to-Face Meeting, NASA Kennedy Space Center.
3. Kolaini, A. R., & Johnson, D. (2025, March 31–April 3). Advancements and current status of direct field acoustic (DFA) testing since inception. 34th Aerospace Testing Seminar, Los Angeles, CA. NASA Langley Research Center. https://ntrs.nasa.gov/citations/20250002796
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5. Davis, J. A., Hale, M. T., Barber, W., & Akers, J. (2024, November 5). Use of spectral analysis of singular values as a test metric for impedance matched multi-axis test trials. 94th Shock and Vibration Symposium. https://ntrs.nasa.gov/api/citations/20240012096/downloads/20240012096.pdf
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7. Spivey, N., Truong, S., Lung, S., & Park, B. (2024, November). Flutter airworthiness clearance effort for a new wing store on F/A-18 B/D Hornet. Presentation at the Aerospace Flutter & Dynamics Council (AFDC), San Diego, CA. (CUI)
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11. Bhamidipati, K., De La Cruz, J., Spivey, N., Hicks, A., Wyen, T., Tilmann, S., & Linck, T. (2025). High temperature accelerometer evaluation in combined thermal-vibration environments. Presentation at the NSMMS Conference, Norfolk, VA.

MATERIALS

1. Park, A. (2025, June 30–July 3). Lessons learned in implementing the NASA 6030 AM standard-based qualification for spaceflight. Asia-Pacific International Conference on Additive Manufacturing (APICAM 2025), Melbourne, Victoria, Australia.

NONDESTRUCTIVE EVALUATION

1. Cramer, K. E. (2025, June 17). NDE considerations for reusable liquid rocket engines. Aerospace Reusable Rocket Engines Technical Interchange Meeting, El Segundo, CA, United States.

PROPULSION

1. Parker, D. S. (2024, December 5 & 9–13). Hydrazine issues assessment. JANNAF; HQ Supply Chain Resiliency Board, Washington, DC; Charlotte, NC, United States.

SENSORS AND INSTRUMENTATION

1. Singh, U. N., & Gaskin, J. A. (2024, November 26–29). NASA sensors and instrumentation: Driving technologies to enable an innovative and prosperous future. Optics and Photonics Taiwan International Conference (OPTIC) 2024, Taipei City, Taiwan.
2. Singh, U. N., & Gaskin, J. A. (2025, May 1). Proceedings of the Infrared Detector Technical Interchange Meeting. NASA Infrared Detector Technical Interchange, Pasadena, CA, United States, August 27–28, 2024.
3. Singh, U. N., & Refaat, T. F. (2024, December 2–5). Atmospheric transmission and transmitter technologies for wind lidar applications operating at 2-micron spectral band. Asia-Pacific Remote Sensing, Kaohsiung City, Taiwan.
4. Singh, U. N. (2024, December 2–5). Active optical remote sensing: Past, present, and future innovations for Earth science missions. Asia-Pacific Remote Sensing, Kaohsiung City, Taiwan.
5. Singh, U. N., Brereton, P., & Lekki, J. (2025, May 19–20). Quantum sensors (QS) for space science: An NESC perspective. Committee on Atomic, Molecular, and Optical Sciences 2025 Spring Meeting, Washington, DC, United States.

SPACE ENVIRONMENTS

1. Wolk, S. J., Aldcroft, T. L., Plucinsky, P. P., Schwartz, D. A., O'Dell, S. L., Minow, J. I., Grant, C. E., Bautz, M. W., Viens, P., & Bissell, B. (2025). Twenty-four years of radiation protection of the Chandra X-ray Observatory. Journal of Spacecraft and Rockets, 62(2), 542–547. https://doi.org/10.2514/1.A36012
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6. Minow, J. I. (2024, October 7–11). Solar wind proton flux on space exposed materials in the interplanetary environment. 16th International Symposium on Materials in the Space Environment & 14th International Conference on Protection of Materials and Structures in the Space Environment, Saint-Raphaël, France.
7. Levine, J. S. (2024, October 7). NASA wants to send humans to Mars in the 2030s – a crewed mission could unlock some of the red planet's geologic mysteries. The Conversation. College of William and Mary.
8. Levine, J. S. (2024, December). Sending the scientists, in Destination Mars: Next Step in the Human Adventure. Popular Science.
9. Minow, J. I. (2024, November 4–8). Solar wind as a space radiation environment in interplanetary space. European Space Weather Week, Coimbra, Portugal.
10. Zheng, Y., Mertens, C. J., Gronoff, G., Petrenko, M., Didgu, C. C., Phoenix, D., Buhler, J., Jun, I., Minow, J., Willis, E., Wiegand, C., & Mullinix, R. E. (2024, November 4–8). NAIRAS atmospheric and space radiation environment model. European Space Weather Week, Coimbra, Portugal.
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12. Jun, I. (2024, November 12–15). Basics of space radiation effects on microelectronics. Korean International Semiconductor Conference & Exhibition on Manufacturing Technology, Busan, South Korea.
13. Kuznetsova, M. M., Bisi, M. M., Boyd, A. J., Bruinsma, S., Georgoulis, M. K., Guo, J., Ishii, M., Jackson, D., Jun, I., Linton, M., Marshall, R. A., Masson, A., Minow, J. I., Opgenoorth, H., Pevtsov, A. A., Reiss, M., Robinson, R. M., Temmer, M., Tsagouri, I., Vourlidas, A., Whitman, K., & Zheng, Y. (2024, December 9–13). Ways forward towards improved space environment understanding and forecasting, Abstract SH23E-06. American Geophysical Union Fall Meeting, Washington, DC.
14. Dawkins, E., Janches, D., Stober, G., Carrillo-Sánchez, J. D., Weryk, R., Hormaechea, J. L., & Plane, J. (2025, April 27–May 2). Detecting meteoroids with the Southern Argentina Agile Meteor Radar Orbital System (SAAMER-OS): Applications for atmospheric and astronomical research. EGU General Assembly 2025, Vienna, Austria. EGU25-12565. https://doi.org/10.5194/egusphere-egu25-12565.
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2. Shimizu, L., Ratcliffe, J., Hickman, H., Tai, W., & Goyal, V. (2025, January 6–10). Modified four-point bending test configuration for fracture characterization of high temperature materials. AIAA SciTech Forum, Orlando, FL, United States.
3. Dawicke, D.S., Leser, W.P., & Hickman, H.K. (2025, August 25). Unconservatism of ANSI AIAA S081B for damage tolerance life analysis of COPVs [Journal Article]. Engineering Fracture Mechanics, Volume 325 25 August 2025, 111290.
4. Shimizu, L., Goyal, V., Taylor, D., & Trautner, C. (2025, January 6–10). Proposed reliability-based damage tolerance guidelines for space systems. AIAA SciTech Forum, Orlando, FL, United States.
5. Obenchain, M., Trujillo, A., Rome, J., Heying, J., Villegas, A., Taylor, D., & Goyal, V. (2025, January 6–10). Toward a fully capable in-space manufacturing ecosystem. AIAA SciTech Forum, Orlando, FL, United States.

SYSTEMS ENGINEERING

1. Wilson, S. (2024, December 11). Statistical engineering at the NASA Engineering and Safety Center. Statistics Conference, Blacksburg, VA.
2. Driscoll, A. (2025, June 17). Advances in stress rupture modeling: A case study for predicting COPV reliability. Quality and Productivity Research Conference, Seattle, WA.
3. Huang, Z. (2025, January 27–30). A unified model for tradeoff of sample size, reliability and risks during product life cycle. Reliability and Maintainability Symposium, Miramar Beach, FL.
4. Holladay, J., Silva-Martinez, J., Morgenstern, W., & Beil, R. J. (2025, April 7–10). Shaping the future of NASA systems engineering: Leveraging voice of the customer insights for agility, innovation, and partnership. 19th Annual IEEE International Systems Conference (SYSCON), Montreal, QC, Canada.

THERMAL CONTROL AND PROTECTION

1. Rickman, S. L.; Walker, W. Q.; Darst, J. J.; Calderon, D. T.; Hagen, R. A.; Brown, R. P.; Bayles, G. A.; Hughes, P. J.; Petrushenko, D., Large Format-Fractional Thermal Runaway Calorimeter, U.S. Patent 12,253,484, March 18, 2025.
2. Splinter, S. C., Johnson, D. M., Goodwin, M. T., Mclain, D. A., Poteet, C. C., Bessire, B. K., Martin, A., Poovathingal, S. J., DuPlessis, V. A., Maddox, J. F., Gore, C., Schwartz, T., "HYMETS Return to Service and Recent Test Campaigns," NSMMS & CRASTE, Norfolk, VA, June 23-26, 2025, Presentation.
3. Rickman, S. L., Introduction to Orbits. Rice Envision Aerospace Academy, Houston, TX, June and July 2025.
4. Rickman, S. L., Introduction to Orbital Mechanics and Space-craft Attitudes for Thermal Engineers. Thermal and Fluids Analysis Workshop (TFAWS) 2025, San, Jose, CA, August 2025.

NASA Technical Memorandums (TM), NASA Technical Publications (TP), NASA Contractor Reports (CR), and Proceedings (CP)

1. NASA/TM-20240012664 Evaluation and Testing of Anaerobic Hydrogen Sensors for the Exploration Ground Systems Program
2. NASA/TM-20240012670 Commercial Crew Program (CCP) Post-flight Reference Radiation Environments
3. NASA/TM-20240012679 NESC Ceramic Oxygen Generator (COG) Technology Development
4. NASA/TM-20240012669 A Proposed Approach for Measuring the Velocity of Detonation in Flexible Confined Detonating Cords
5. NASA/TM-20240012860 Lunar Glove Thermal and Durability Analysis, Test, and Failure Mitigation
6. NASA/TM-20240013617 Mars Sample Return (MSR) Program - Mars Ascent Vehicle (MAV) Project Ascent Flight Phase Independent Modeling and Simulation (M&S)
7. NASA/TM-20240013031 Expansion of Check-Cases for 6DOF Simulation
8. NASA/TM-20240014203 NASA Engineering and Safety Center Lunar Rover Design Concepts Assessments
9. NASA/TM-20240014249 State of the Art (SOA) in Composite Cryotank Technology
10. NASA/TM-20240014860 Computational Fluid Dynamics (CFD) Assessment of Ascent Abort-2 (AA-2) Axial Force Anomaly/Multi-Purpose Crew Vehicle (MPCV) Launch Abort Vehicle (LAV) Powered Aero Database Development using FUN3D
11. NASA/CR-20240015749 Humans to Mars, But How Many? A Historical Review of Crew Size Determinations for Mars Missions
12. NASA/TM-20240016466 Self Reacting-Friction Stir Weld (SR-FSW) Anomalies
13. NASA/TM-20240016463 Exploration Systems Exterior Lighting Design Guidance
14. NASA/TM-20240016469 Lunar Suit Tribocharging Risk Assessment
15. NASA/TM-20250001469 Trade Space Analyses: Balancing Crew and Mission Design Parameters: Candidate Mars Master Task List
16. NASA/TM-20250001481 Perform Navigation Expert Peer Review of Space Launch System (SLS) Block 1 B (B1B)
17. NASA/CR-20250001474 Single Integrated Flux Files to Account for Spacecraft Attitude Motion in Meteoroid Risk Assessments Using the NASA MEM3 and Bumper Codes
18. NASA/TM-20250002739 Johnson Space Center (JSC) Mission Control Center (MCC) (Building 30) Backup Electrical Power Assessment
19. NASA/TM-20240000329 Through-Width and Through-Thickness Edge Effects on Tensile Properties of Thick AA2219 Plate
20. NASA/TM-20250003534 Extravehicular Mobility Unit (EMU) Water Management
21. NASA/TM-20250004074 A Methodology to Evaluate the Feasibility of Descoping Nondestructive Evaluation (NDE) Fracture Control Requirements in NASA-STD-5019A
22. NASA/TM-20250004056 Docking Loads Due to Low-Gravity Propellant Motion
23. NASA/TM-20250004116 Meteoroid and Orbital Debris (MOD) Pressure Vessel Failure Criteria
24. NASA/CP-20250004471 Proceedings of the Infrared Detector Technical Interchange Meeting
25. NASA/TM-20250005960 Best Practices for Organizational Resilience in the International Space Station (ISS) Program
26. NASA/TM-20250008583 Cold Electronics for Lunar Missions
27. NASA/CR-20250008764 Experimental Mode Orthogonality and its Consequences
28. NASA/TM-20250010561 Hubble Space Telescope and Swift Observatory Orbit Decay Study

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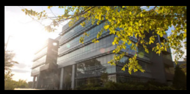

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