National Aeronautics and
Space Administration

NASA ENGINEERING & SAFETY CENTER

2024
NESC
TECHNICAL UPDATE

Annual Report of NESC Technical Activities

www.nasa.gov

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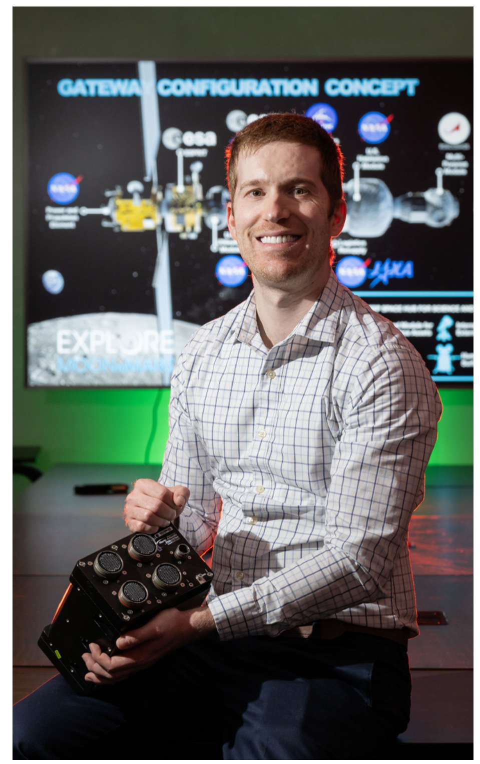

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SAFETY STARTS WITH ENGINEERING EXCELLENCE

Except where noted, all photographs and illustrations are NASA images.

Established in 2003 in response to the Columbia accident

The Columbia Accident Investigation Board specified a need for a technically strong, program-independent resource to provide an alternative perspective on difficult technical issues and provide independent technical investigations for NASA programs and projects.

Columbia, STS-1, at Launch Pad Complex 39A

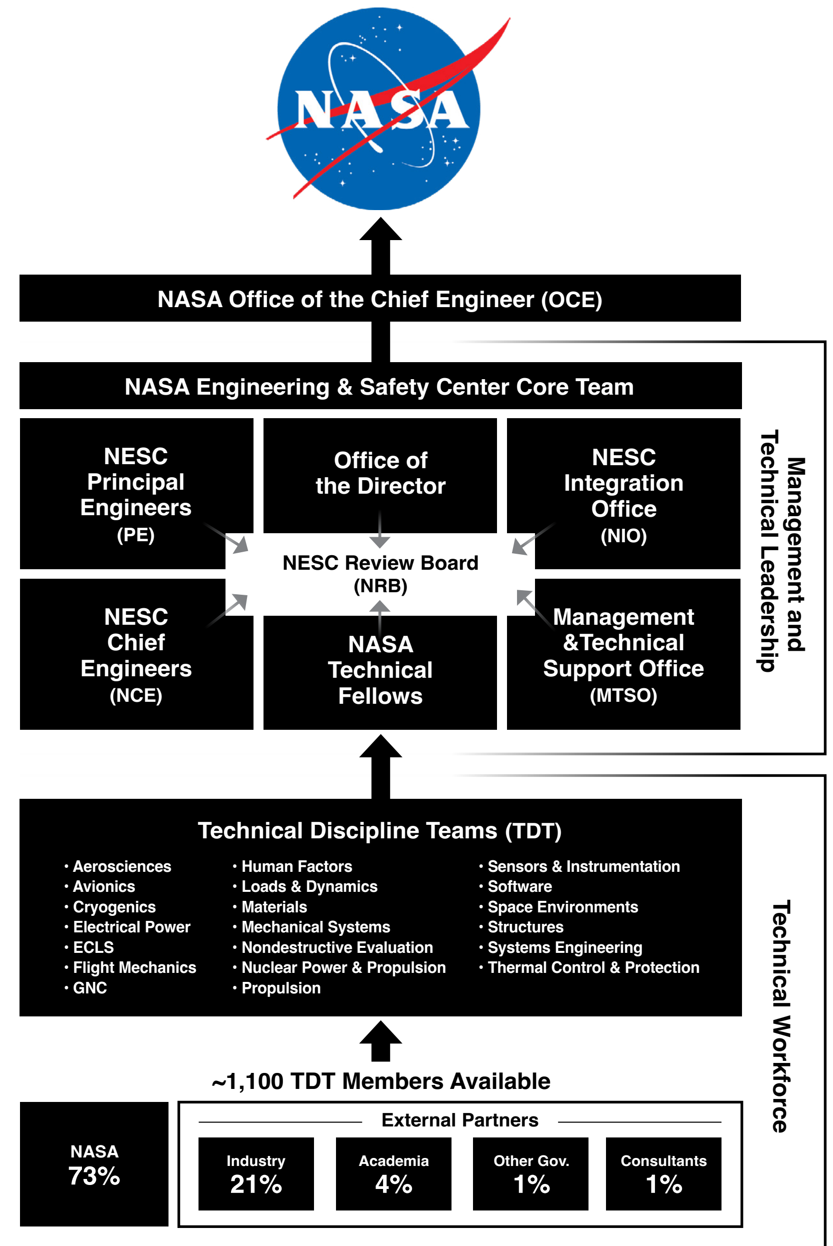
NASA ENGINEERING & SAFETY CENTER

Performing value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success.

The NESC also engages proactively to help NASA avoid future problems.

For general information and requests for technical assistance visit:

NASA.GOV/NESC



Independence and Objectivity

The NESC performs technical assessments and provides recommendations based on independent testing and analysis. An independent reporting path and funding from the OCE help ensure objective technical results for NASA.

Engineering Excellence

The NESC draws on the knowledge base of technical experts from within NASA, industry, academia, and other government agencies. Collaborating with leading engineers allows the NESC to consistently optimize processes, strengthen technical capabilities, and broaden perspectives. This practice further reinforces the NESC's commitment to engineering excellence.

A Unique Resource

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 unbiased technical assessments to enable more informed decisions.

Artist Cece Bibby painting the "Sigma 7" logo on Mercury spacecraft with Astronaut Wally Schirra, 1962.

Origin of NESC Insignia

"I named my spacecraft Sigma 7. Sigma, a Greek symbol for the sum of the elements of an equation, stands for engineering excellence. That was my goal, engineering excellence." - Wally Schirra

The NESC's insignia has its roots in the early Mercury program. For the NESC, the sigma also represents engineering excellence. While the "Sigma 7" represented the seven Mercury astronauts, the "Sigma 10" in the NESC insignia represents the 10 NASA centers. The NESC draws upon resources from the entire Agency to ensure engineering excellence.

MESSAGE FROM NASA LEADERSHIP

In spaceflight and aeronautics, progress often demands tough decisions, and I frequently rely on the NESC to help navigate those challenges. As NASA's Chief Engineer, I'm tasked with having a thorough understanding of complex technical issues and making informed recommendations to leadership. The NESC plays a key role in ensuring I have the best information at hand. Their technical expertise and collaborative, cross-disciplinary approach are invaluable. This year alone, they've contributed to critical areas like analyzing Artemis I data, addressing issues with parachutes, valves, flight sensors, and life-support systems, and providing updates on new materials and technologies. Their ability to unite experts from across the Agency with a one-NASA mindset focused on mission success makes all the difference. When I need to make those hard calls, I know I can count on the NESC with their network of NASA and industry engineers for the trusted insight that helps drive mission success.

Joseph W. Pellicciotti
NASA Chief Engineer

As the NASA Chief Health and Medical Officer, I deeply value the collaboration with the NESC in investigating and resolving program issues and risks. Numerous cross-discipline issues have been jointly investigated and resolved by working hand in hand with the NESC. It is critical for NASA to engage the entire technical community to ensure the best solutions are brought forward, and the NESC has been extremely instrumental in enabling and implementing these activities. As a physician in an engineering world, charged with the oversight of the human portion of human spaceflight, I truly appreciate this partnership and look forward to future collaborations with the NESC, further strengthening NASA's commitment to successfully expanding human spaceflight.

Dr. James D. Polk
Chief Health and Medical Officer

NESC Members, May 2024

Tim R. Wilson, NESC Director

MESSAGE FROM NESC DIRECTOR

NESC assessments this past year have supported the Commercial Crew Program's transition from design to testing to operations; the Artemis Program's preparations for its first crewed mission; and the Gateway and Human Lander System Programs' continuing development. The NESC has also been providing expertise and independent analysis to ensure the safety of those aboard, or traveling to and from, the International Space Station. And because we are a resource for the entire Agency, NESC teams have also supported the Science and Aeronautics Mission Directorates and many of their projects in various stages of development and operation.

The NESC's reach has also provided a unique opportunity to address crosscutting issues of importance to the Agency: long-term issues like additive manufacturing, material ignition and flammability control, valve design standards, and carbon overwrapped pressure vessels. Some of the crosscutting assessments we have completed this past year are profiled in this Technical Update.

Organizationally, the NESC falls under the NASA Office of Chief Engineer and can tap into a vast reservoir of technical expertise—both within and beyond NASA—through the NESC Technical Discipline Teams for a depth of technical knowledge and experience not available within any single NASA program or center. This gives us the technical capability and independence we need to provide unbiased technical evaluations outside a home organization. That world-class independent technical capability is what was envisioned at our founding, and as we enter our third decade it is the standard by which we add value. Over the years, we have touched every mission directorate by providing a conduit for NASA programs to connect with the rest of the Agency to quickly get the expertise needed, where it is needed. Whether it is leading a complex, multi-disciplinary assessment for one of NASA's flagship campaigns, or locating the individual with unique expertise to assist a science mission, the NESC is devoted to providing whatever is necessary to continue to move NASA's missions safely forward.

Tim R. Wilson
NESC Director

NESC ENGAGEMENT IN TOP AGENCY TECHNICAL ISSUES

Q&A with NESC Deputy Director Michael Kirsch

In 2024, the NESC actively worked more than 150 requests from NASA stakeholders looking for technical solutions, sometimes in the form of second opinions and insight on designs or help in investigating anomalous behavior or identifying root cause. The goal with each request is always to help find the source of the problem and identify a path to resolution or mitigation, and ultimately, reduce some of the risk inherent in spaceflight.

After 20 years and fielding more than 1,300 requests, the NESC's job of buying down risk for the Agency isn't getting any easier, especially with NASA and private companies in active pursuit of getting humans to the Moon and Mars. So the organization counts on its methodology for prioritizing requests and identifying areas where it can best contribute to the Agency's overall risk posture. And in cases where reducing risk is not an option, it can ensure the stakeholder fully understands the issue and can make risk-informed decisions.

In this Q&A, NESC Deputy Director Michael Kirsch talks about how the organization supports the Agency's efforts to minimize the risks of space exploration.

How does the NESC decide what projects to take on and how does risk factor into that decision?

The NESC has an initial evaluation process, where we evaluate the work requested against several criteria, one of which looks at the level of risk that issue represents for the Agency. We've also used a risk matrix to look at the likelihood and consequence of a risk occurring. Where we start to wring our hands is when an issue falls into a moderate likelihood and high consequence. This is the beginning of the red-risk category, and we do pay more attention to requests that fall in this area. That said, I always like to temper our evaluation of risk. I think NASA is really good at predicting and understanding the consequence of failure, but we're not as good as we think we are in predicting likelihood. That's a very tricky parameter, especially when we have anything less than a 100% understanding of all of the system nuances. However, when program or Agency leadership feels a problem is complex enough to warrant a second look, then it's very likely we will take on that work irrespective of the severity of the risk.

> *"I think NASA is really good at predicting and understanding the consequence of failure, but we're not as good as we think we are in predicting likelihood. That's a very tricky parameter, especially when we have anything less than a 100% understanding of all of the system nuances."*

Do perceptions of risk differ between human and robotic spaceflight, and does that affect what requests we take on?

On paper, no. Loss of mission is loss of mission. But our tolerance for risk will absolutely be less in human spaceflight (HSF), and appropriately so, and that's not limited to flight crews. It includes the extended NASA family and the public.

That human-life component with crew safety does often keep us focused on HSF programs.

Some of NASA's science programs have a higher risk tolerance. In fact, the Commercial Lunar Payload Services (CLPS) Program was deliberately contracted with private companies to design, build, and fly systems to the Moon with very little to no government insight, a decision made in order to get some low-cost scientific benefit from some of the commercial endeavors. Those missions have begun flying with varying degrees of success. The NESC weighed in on one underway mission when it had propulsion system challenges. We provided options for understanding the problem, even though the mission at that point was not salvageable. But our suggestions for further exploring the system design will help follow-on missions leveraging these same technologies. That work led to other CLPS projects asking for propulsion experts to peer review their designs. The NESC was able to help them look for easy wins on risk-reduction changes, while still preserving the intent of the CLPS contract. I anticipate we will do more of that in the future.

In a more recent example, the NESC played a large role in helping the Agency understand the risks of bringing our astronauts home on Starliner. And when the Agency decision was made to return Starliner uncrewed, we participated to help ensure we weren't creating excessive risk to the public in the event of an uncontrolled spacecraft return.

In what Agency or Program risks is the NESC currently involved?

I feel we have a diversified portfolio on how we apply our resources for the Agency with reach into just about every mission directorate, though our largest footprint exists in Exploration Systems and Space Operations because of the implications to crew.

There are key risks in each directorate that we are working. In Space Operations, I am very concerned about the ISS Russian segment, PrK, its remaining life, and how we manage the risk of catastrophic failure. And the NESC is active in the Engineering Review Boards and Flight Readiness Reviews for each of the Commercial Crew Program (CCP) crewed launches.

> *"We have a team looking at the Orion char loss flight anomaly to make sure we haven't missed anything in understanding root cause and in our ability to predict how the heatshield will behave for future Artemis missions."*

In Exploration Systems Development, we have a team looking at the Orion char loss flight anomaly to make sure we haven't missed anything in understanding root cause and in our ability to predict how the heatshield will behave for future Artemis missions. We also want to leverage what we've learned from CCP to understand the robustness of the Space Launch System's autonomous flight safety system, especially since the Department of Defense plans to remove the human-in-the-loop control of the launch destruct system.

In Aeronautics, we're looking at how strain gages were implemented on X-59 hardware. There are risks associated with using electronics in aircraft fuel systems, and we want to ensure those have been sufficiently managed. The NESC is also developing energy-reduction hardware to help the X-59 Program bring that risk down to lower levels.

There are less urgent concerns with the Human Landing System Program given where they are in their lifecycle. Since test flights will predominately be uncrewed, the commercial providers have a lot of freedom to "try and fail and fix" and learn from the actual hardware. That said, we are participating in collaborative efforts for more technical risk reduction, principally around cryogenic fluid management and material flammability studies. Storing and transferring cryogenic fluid in zero or low gravity is a tough technical challenge but critical to the architecture we are relying on for return to the lunar surface. The NESC is leveraging its experience in these systems to help commercial providers retire those risks sooner rather than later.

Spacesuits are always a challenge. The suit is almost a spacecraft in itself with lots of moving parts and complex interfaces with subsystems that have to work in extreme environments. So, we monitor the acquisition and development of the next generation of suits, again because those will be critical to humans returning to the lunar surface.

In what ways does the NESC inform Agency/Programs on their risk postures?

There are many avenues we rely on to communicate our concerns, primarily through our participation in engineering review and program control boards, but also at program or Agency flight readiness reviews if we feel strongly about something. On occasion we will write an NESC position paper, which we have done on some of the technical topics discussed earlier, in particular the ISS PrK. These are elevated to Agency leadership through the NASA Chief Engineer.

What makes the NESC equipped to evaluate risk and why should the Agency/Programs care what we think?

The backbone of the NESC is the NASA Technical Fellows. We hire people who have considerable experience developing, testing, and certifying hardware in complex systems. With this background, we know they will have an appreciation for what can go wrong and what it takes to be good enough for a mission. And interfacing with complex systems means they can appreciate how their discipline interacts with others. This gives us credibility when talking to engineering and program leadership.

NASA often uses the Seven Elements of Flight Rationale when making decisions on whether or not a spacecraft is ready for flight. Does the NESC use this in their assessments?

I think everyone has different ways of leveraging those seven elements. I use it as a guide to help us understand what we don't know or how confident we are in what we do know. I've seen them applied in other ways—as a "go-no-go" gage, in a binary function to determine whether an element is good or bad, or as a gradient of understanding for each element. Regardless of how it is used, its intent is to help communicate how much risk might be remaining after we've done the engineering work. Practically, the NESC doesn't require its use, but we do participate with programs when they evaluate the seven elements and share our experiences and perspectives.

You are a big proponent of knowing your margins, to the point of hanging that message in your office and in the NESC's main conference room. Why is this important to you?

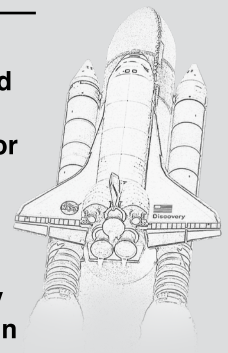
Knowing your margins is fundamental to certifying hardware for a mission and being confident in predicting how the hardware will behave for the intended environment. It's leveraging first-principle physics, knowing the capability exceeds the need by some measurable amount. Even when we prove analytically that the capability exceeds the need, we like to take the next step and prove it in test, and ideally, test it to the bounding case or the worst possible case we expect to see in the use environment. That message was derived from those seven elements and helps us describe how confident we are that the hardware or system will behave in a predictable way.

Does the NESC have a risk watchlist? If so, how or when do items move to the top of that list, fall off, or become a crosscutting issue?

We don't have a formal watch list, but we have a broad portfolio of in-progress activities. Tim Wilson (NESC Director) and I have a good understanding of how each task fits within that portfolio and track when something might need to be emphasized or de-emphasized in any given timeframe. We have monthly financial reviews where we look at all the work underway at the NESC and can increase our investment or slow a task down if it has been overcome by a higher-priority task. It's a constant adjustment process, especially with more programs in the flight phase where real-time involvement can pull our resources in a different direction at a moment's notice. But that's where the NESC often does its best work. We can pull together a team quickly and with the right skills to help the Agency find the solutions they need or understand the risks involved.

Seven Elements of Flight Rationale

by Stan Graves, formerly of ATK Thiokol



For the STS-114 Return to Flight, engineers developed seven steps as a way to approve technical issues for flight—the Seven Elements of Flight Rationale.

Critical issues must satisfy each of the following to gain approval for flight:

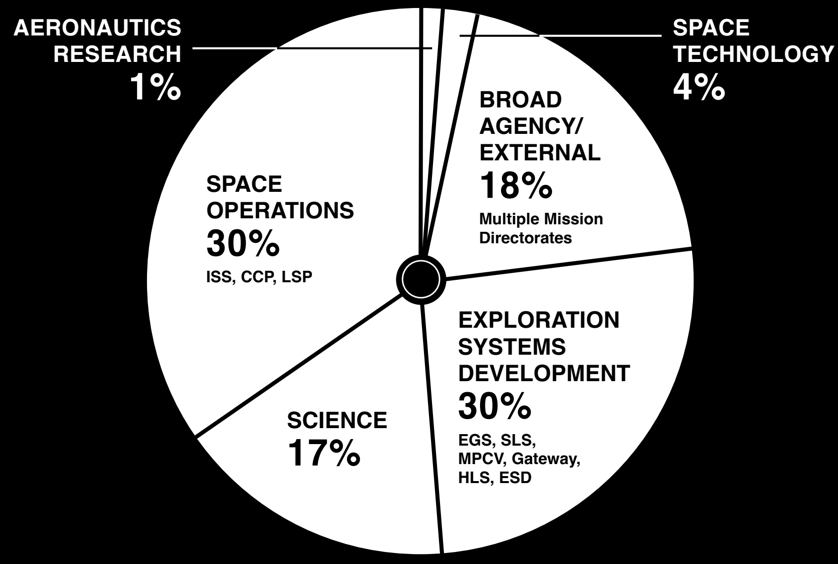
1. **Achieve Solid Technical Understanding**
2. **Compare the Issue Relative to the Experience Base**
3. **Establish the Bounding Case(s)**
4. **Identify Self-Limiting Aspects**
5. **Understand the Margins**
6. **Assess Based on Data, Testing, and Analysis**
7. **Address Interactions with Other Elements and Conditions**

NESC TECHNICAL ACTIVITIES

NESC technical activities are grouped into the following broad categories:

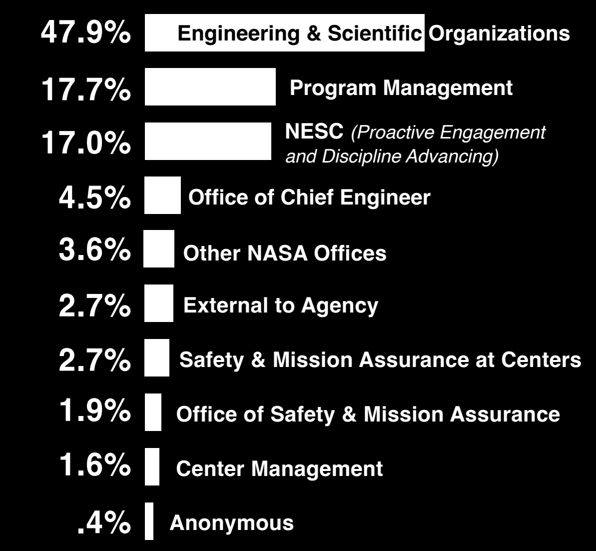
- Crosscutting Work
- ESDMD Design & Integration
- Sustaining ISS
- CCP Insight
- Aeronautics
- Science

- **1,314 Accepted Requests since 2003, 75 in FY24**
- **79 Yearly Average of Accepted Requests**
  (past 5 years)
- **156 In-Progess Requests**



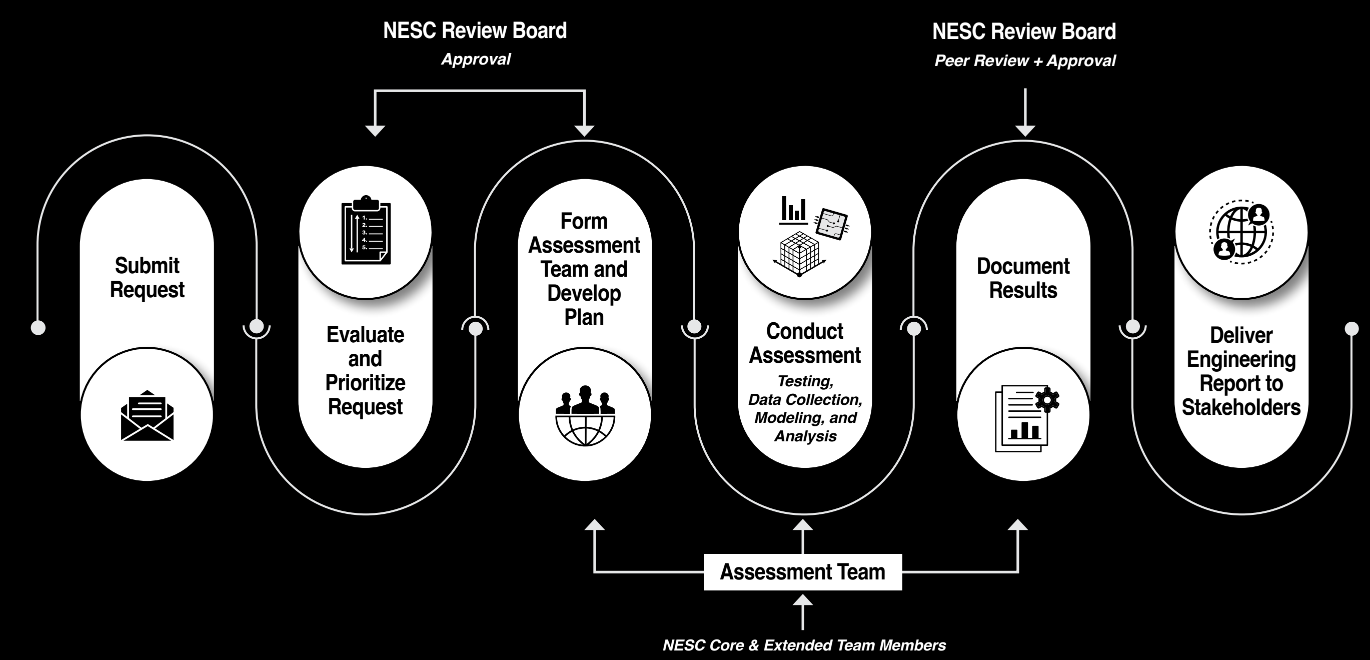
Accepted Requests by Mission Directorate

FY20-FY24



Sources of Accepted Requests

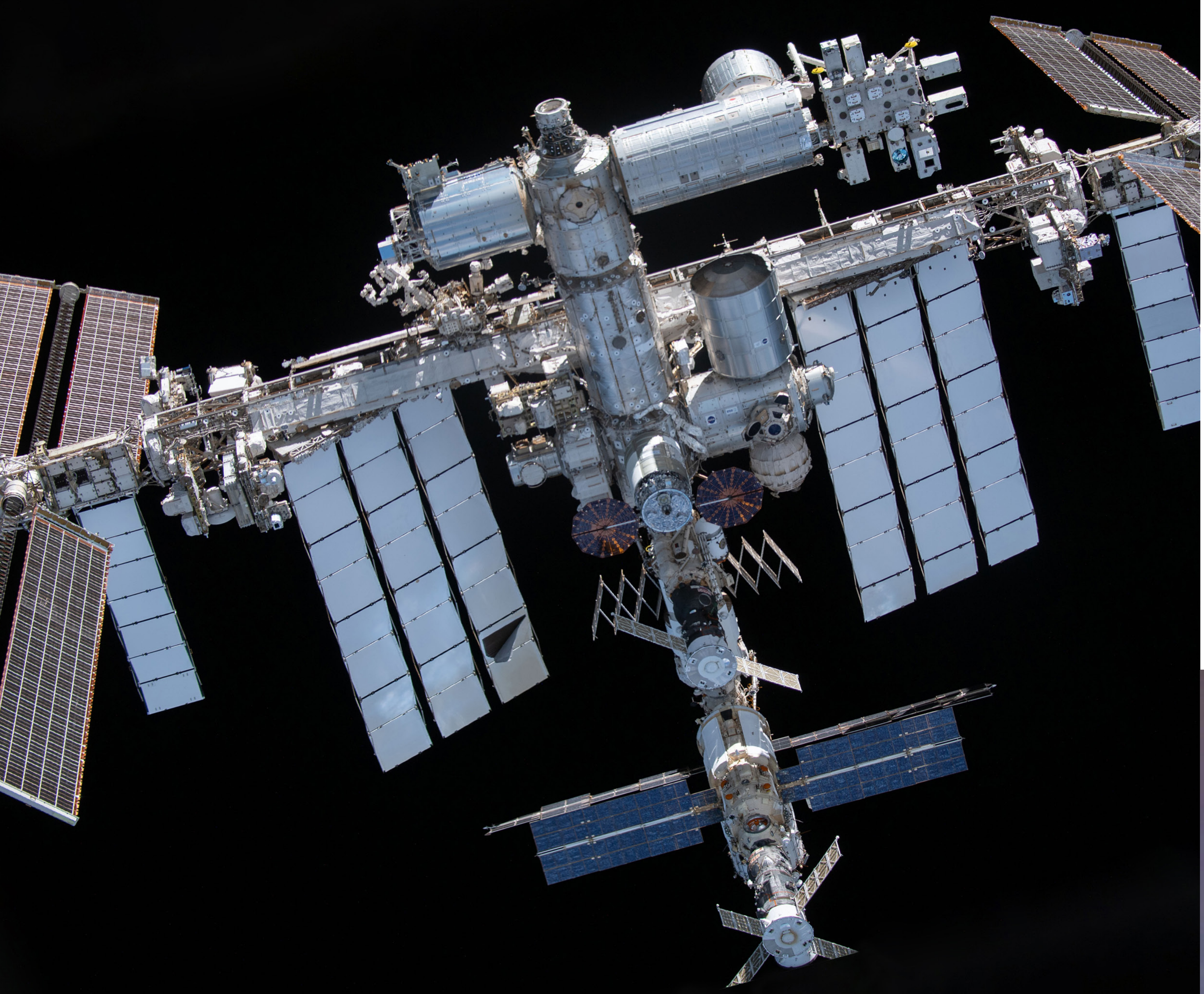
FY04-FY24



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.

Data as of September 30, 2024



ISS pictured from the SpaceX Crew Dragon Endeavour.

SUSTAINING ISS

ISS PrK Independent Assessment

The NESC is assessing the ongoing leak in the ISS Russian segment, PrK, the segment's remaining life, and how to manage the risk of potential failure.

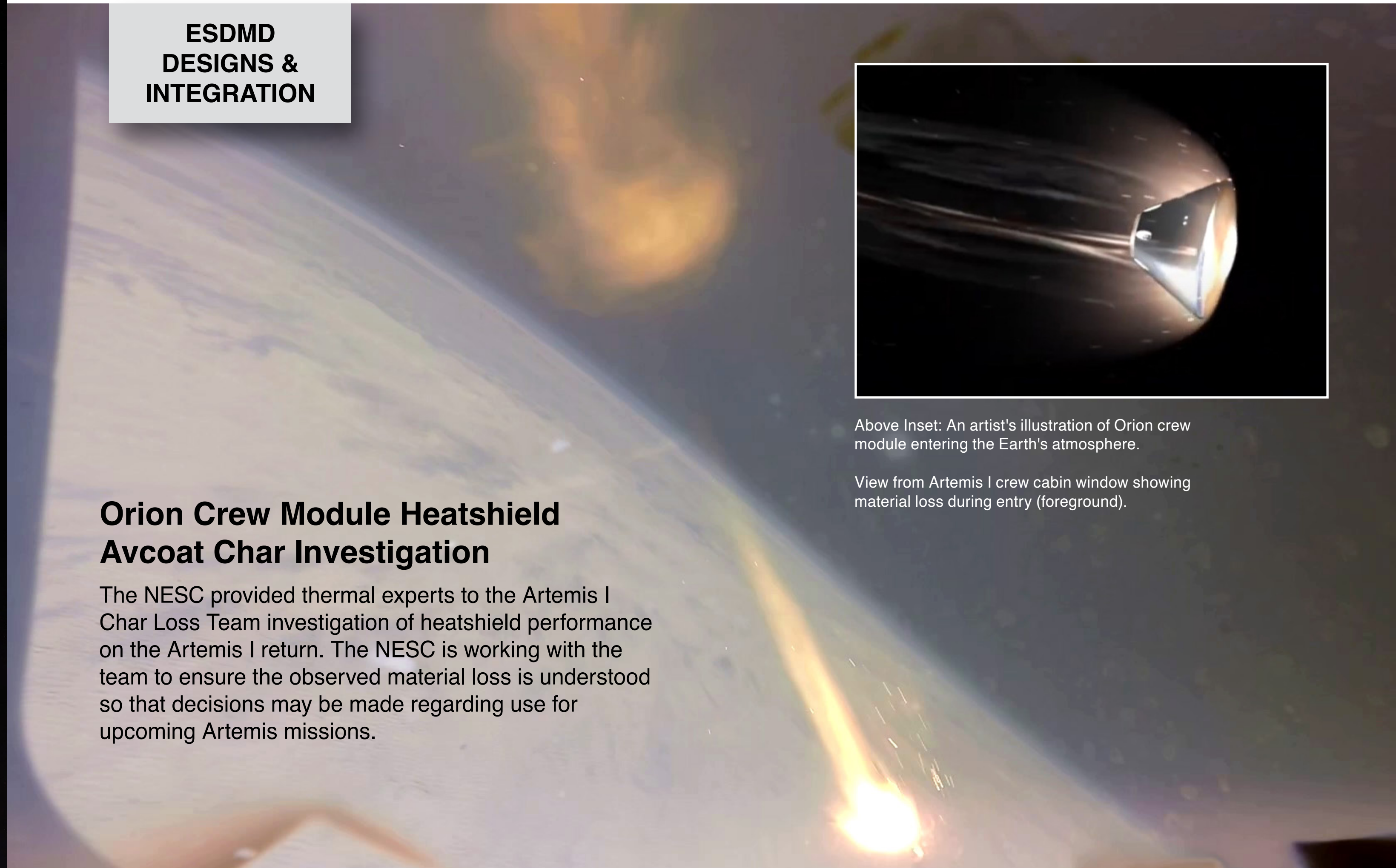
In-Progress Technical Activities

Data as of October 2024

The portfolio of current NESC technical activities reaches across mission directorates and programs encompassing design, test, and flight phases.

- Deep Dive Support of Propulsion System
- SLS DP Measurement Oscillation Investigation
- HLS Cryo Fluid Management - Cryocooler Risk Mitigation
- Lunar Terrain Vehicle Standards Evaluation
- Gateway/HALO Thermal Coating System
- HLS Elevator System Peer Review
- Artemis III Crew Module Hydrazine Crossover Valve
- Electrostatic Discharge-Induced Ignition Risk in Suits
- Textile Development for Oxygen Enriched Atmospheres
- Facility LN2 Dewar/Supply System for LaRC
- Lunar Environment Monitoring Station Plume Damage Simulation
- Nitrox Blow-Down Thermal Analysis
- JPSS-2 Investigation and Spacecraft Charging
- STMD Cryo Fluid Management Roadmapping
- ISS Water Separator Motor
- Payload Interface Logic and Definition
- Resolution of CCP Flight Anomalies
- Linear Covariance Tool Development
- Total Ionizing Dose Tolerance of Power Electronics on Europa Clipper
- Lunar Landing Tip-over Fishbone Exercise
- NDSB2 Passive Element Radiation and Internal Charging
- Twist-Capsule Redesign Review
- CCP Helium Leak Investigation
- Evaluation of Franjible Joints
- ISS Deep Dive into Vehicle Software
- Lifetime and Capability of Inconel Heat Exchanger

ESDMD DESIGNS & INTEGRATION



Above Inset: An artist's illustration of Orion crew module entering the Earth's atmosphere.

View from Artemis I crew cabin window showing material loss during entry (foreground).

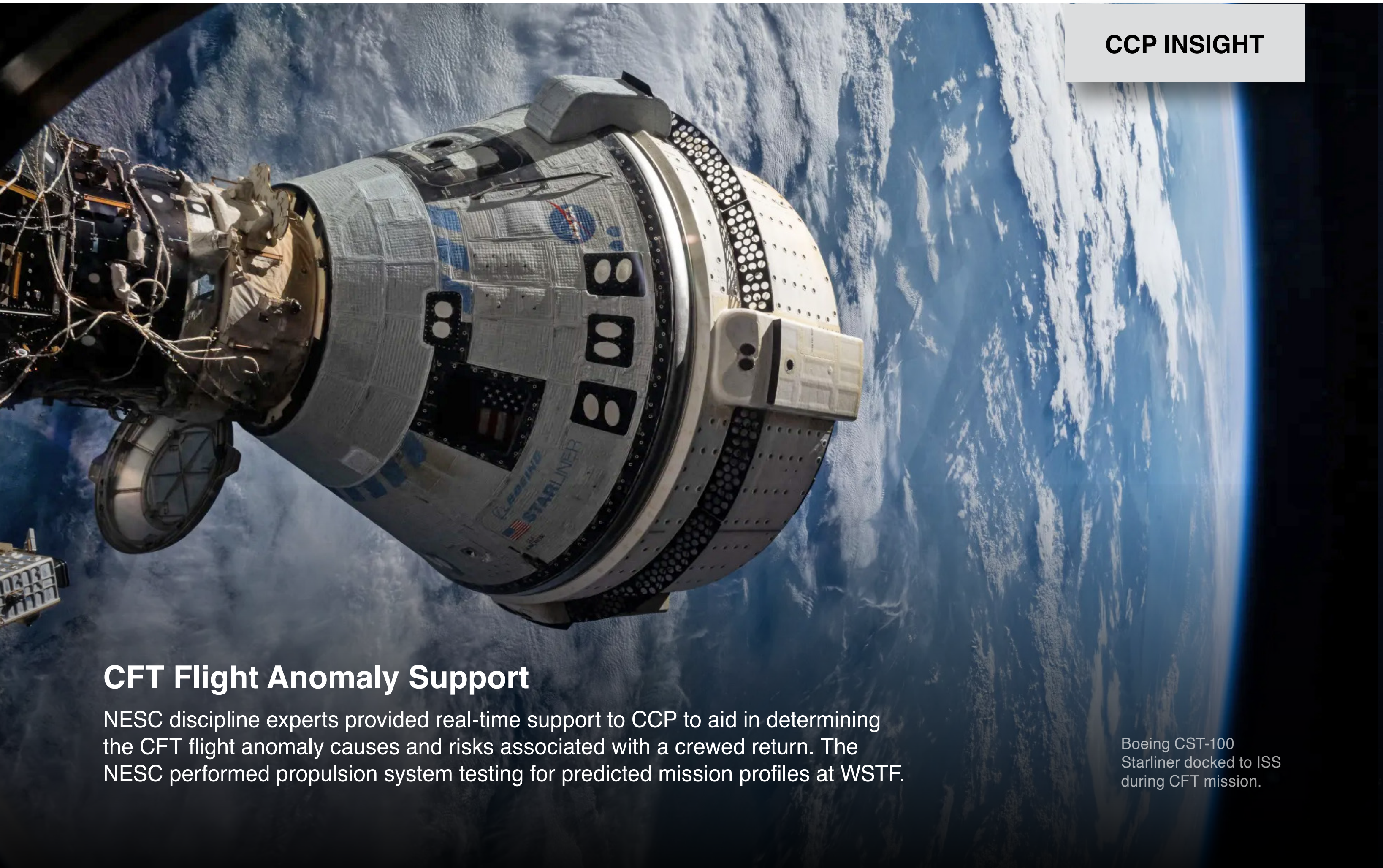
Orion Crew Module Heatshield Avcoat Char Investigation

The NESC provided thermal experts to the Artemis I Char Loss Team investigation of heatshield performance on the Artemis I return. The NESC is working with the team to ensure the observed material loss is understood so that decisions may be made regarding use for upcoming Artemis missions.

In-Progress Technical Activities

continued

- Failure-Tolerant Avionics for Crewed Space Systems
- Resolving Content Issues with NASA-HDBK-5023 (Frangible Joints)
- DRAFT NASA-HDBK-5025 (Pyrotechnic Components)
- Support for Balloon Program Quality Assurance Evaluation
- Broad ECLSS and EVA Support to ESDMD and SOMD
- C-103 Grain Size Sensitivity Testing
- ESDMD Lunar Reference Frame Action
- Super Guppy Rescue Loader Hydraulics
- SMD ESCAPADE AM Ti Tanks Implementation
- Lunar Boot Thermal Test Program, Analysis, and ASTM Standard
- Propagating Arcing Potential
- SLS Core Stage/EUS: 2219-T851 Thick Plate Short Transverse Ductility
- ISS PrK Independent Assessment
- Energy Modulator Design-Iterations and Re-Qualification Testing
- Solar Energetic Electron Environments
- Carbon Plume Mapper Mirror Investigation
- Navigation Expert Review of SLS Block 1B
- NISAR Reflector Thermal Issue
- Goddard Large Vibration Test Facility Anomaly
- Agency Ignition Control Requirements
- Nova-C Lander Propulsion Schematic Review
- Human Factors Support for Ames Arc Jet Complex Modernization
- Flight Projects Mission Critical Telemetry/Commanding Availability
- Energy Modulator Box-Stitch Upgrade Testing
- EGS ML1 Heritage Cryo Piping Assessment
- JSC Mission Control Center Backup Electrical Power
- 20K Cryocooler Support
- HLS/Gateway Docking Loads Due to Low-Gravity Propellant Motion
- Copper Wire Bond Evaluation Support
- Dragonfly Capsule Dynamic Stability Ballistic Range Testing
- Smart Initiator DLAT Wirebond at Low Temp
- Single Event Latch-up in Commercial Electronics: Risk Assessment/Mitigation
- Updated Reliability Evaluation of MPCV SM Fairing Panel FJ for Artemis II+
- CCP GPS Design Deep Dive
- NASA Valve Standard
- HLS Low-G Slosh Modeling Support
- HLS Flight Mechanics Abort/Failure Analyses
- Plume Surface Interactions with GNC During Lunar Descent
- HLS Guidance Algorithm Evaluation
- Psyche Cold Gas Thruster Technical Advisory Team
- Moon to Mars Artemis II Critical Event Assessment Review
- SLS Debris Resolution Team Support
- Parachute Design Guidelines Revision and Development
- SX50 Pressure Sensor Anomaly
- Mass Properties Evaluation of CCP Providers
- Cryogenic Fluid Management Support to DARPA Project
- Nuclear Electric Propulsion Technology Maturation Plan Non-Advocate Review
- Spacesuit Material Wire Ignition Risk
- Evaluate Feasibility of Alternative to NASA STD 5019
- Landing Risk Assessment
- Cold Electronics for Lunar Missions
- Systems Engineering SME Support to Commercial LEO Development Program
- Flight Deck Automation System Integration Assessment Transport Category
- Dichloromethane Bond Testing Data Gap
- PFE Microgravity Compatibility Test
- X-59 Fuel Tank Assessment
- SpaceVPX Interoperability Open Standard
- CO2 Removal Expertise for JAXA I-Hab
- MBSE Support to Advanced Capabilities
- HFE Cleaning and Thermal Solvent Replacement and Qualification
- Orion Crew Module Heatshield Avcoat Char Investigation
- DaVinci Mission Technical Support
- Artemis I Orion PCDU Latching Current Limiter
- Pyro Cable Analysis
- Lunar Suit Tribocharging
- Friction Stir Welding Support

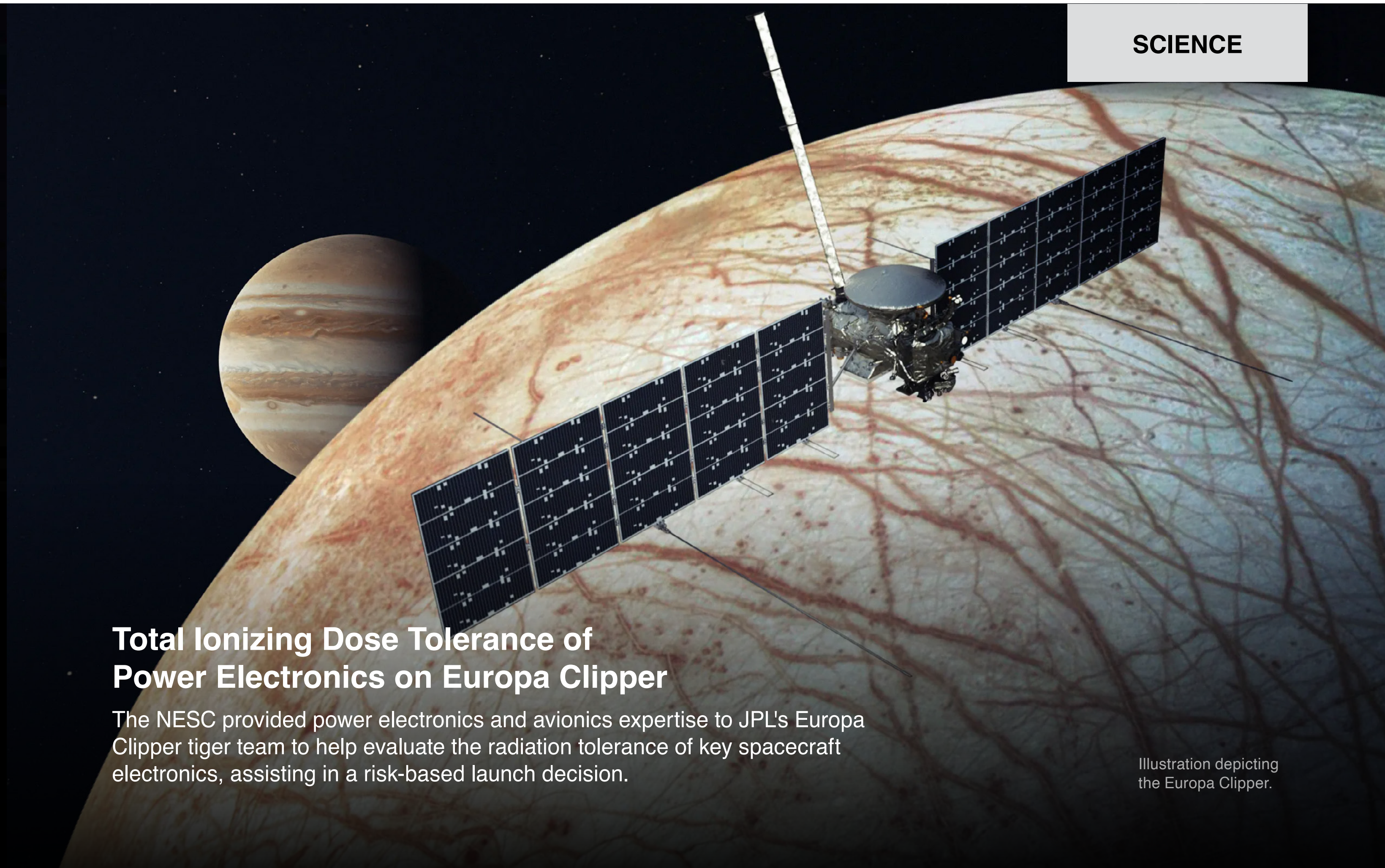


CCP INSIGHT

CFT Flight Anomaly Support

NESC discipline experts provided real-time support to CCP to aid in determining the CFT flight anomaly causes and risks associated with a crewed return. The NESC performed propulsion system testing for predicted mission profiles at WSTF.

Boeing CST-100 Starliner docked to ISS during CFT mission.



SCIENCE

Total Ionizing Dose Tolerance of Power Electronics on Europa Clipper

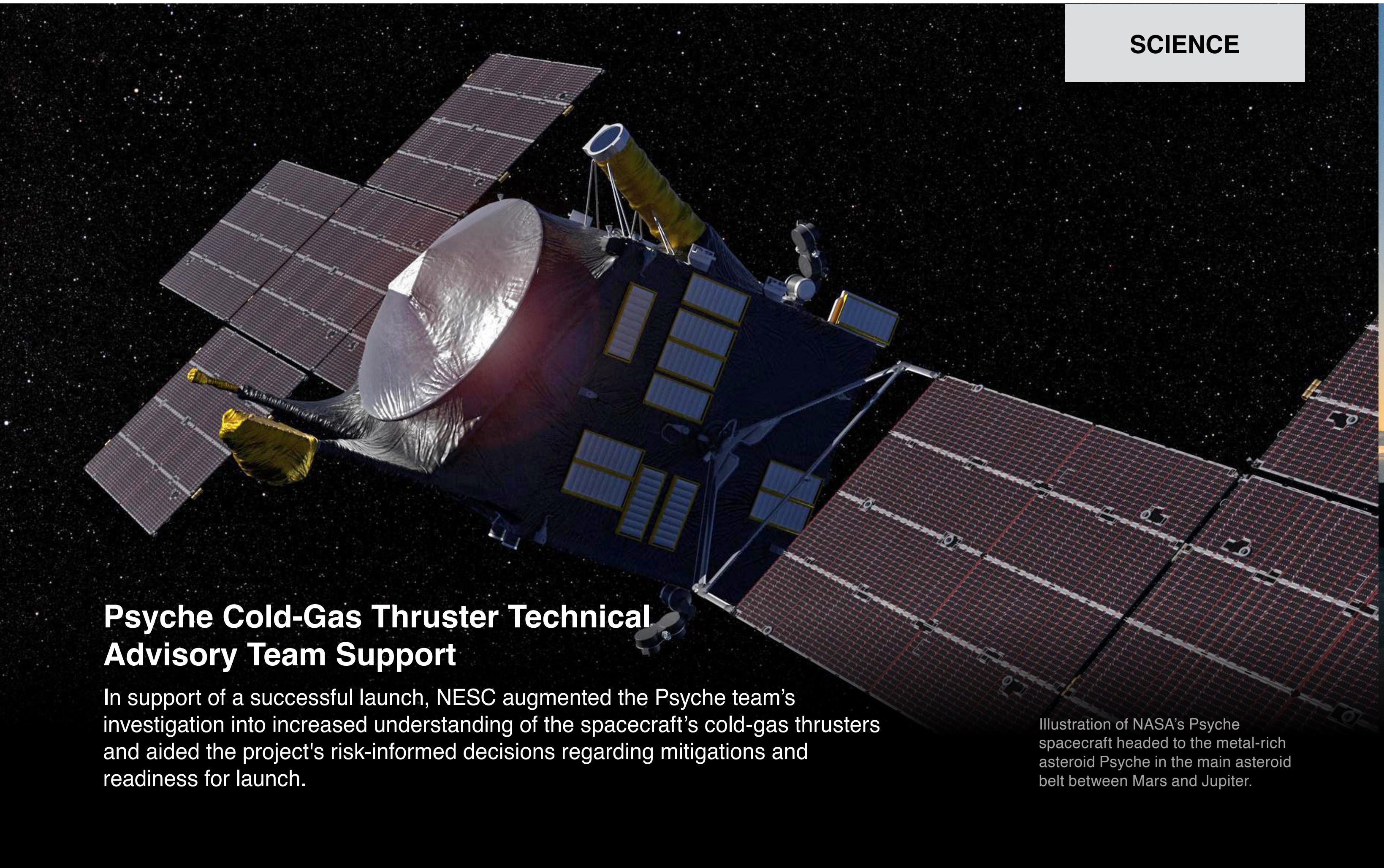
The NESC provided power electronics and avionics expertise to JPL's Europa Clipper tiger team to help evaluate the radiation tolerance of key spacecraft electronics, assisting in a risk-based launch decision.

Illustration depicting the Europa Clipper.

In-Progress Technical Activities

continued

- Sandia National Lab Cooperative Agreement
- Multi-Purpose Crew Vehicle Explosive Transfer Line
- Mechanical Model Development and Parameter Selection for Propellant Slosh
- Dome Ti-NTO Ignition Spots
- NEPP Industry Leading Parts Manufacturer Pathfinder
- Specifying Optical Surfaces to Control Near-Angle Scatter at <100 milli-arc
- Energy Modulator Extension Testing
- Display Management Computer Reset Anomaly
- Composite Consult for New Launch Vehicle Application
- Hardline O2 and Fire Response
- Self-Reacting Friction Stir Weld Anomalies
- Material Flammability in Lunar Gravity
- Programmable Logic Device Guidance and Standard
- EMU Water Management
- Cracked Samples for NDE Standards
- Dynamic Pitch Testing of Capsule at Transonic Speeds
- Technical Support for Human System Interactions in Closed Breathing Systems
- Lessons Learned on Possible Incompatibility DART with its NEXT-C Ion Engine
- SubC Safety Review
- Updates and Modernization of the CEA Code
- SLS Core Stage 2219-T87 Thick Plate
- Power & Propulsion Element Battery Safety
- Dragonfly Dynamic Stability
- Hot-Fire Testing of 5 lbf Class Reaction Control System Thrusters
- Study of Material Sensitivities to N2O4/MON Exposure
- Oxidizer Tank Design and Qualification
- ECLSS-ATCS Review
- Frangible Joint Working Group
- Cross-Program Exposure Testing
- EUS COPV Helium Tank with Large Grain Aluminum Alloy
- CCP Fracture Control Risk Reduction
- Gateway PPE COPV Damage Tolerance Life Support
- AACT Risk Reduction Project - inSitu Monitoring Category
- AACT Risk Reduction Project - Metallurgy Category
- Spacecraft Fire Safety Standard



SCIENCE

Psyche Cold-Gas Thruster Technical Advisory Team Support

In support of a successful launch, NESC augmented the Psyche team's investigation into increased understanding of the spacecraft's cold-gas thrusters and aided the project's risk-informed decisions regarding mitigations and readiness for launch.

Illustration of NASA's Psyche spacecraft headed to the metal-rich asteroid Psyche in the main asteroid belt between Mars and Jupiter.

- Frangible Joint Technical Support to LSP
- Frangible Joint Technical Support to SLS
- Hot Gas Intrusion in Engine Bays
- Thermophysical Properties of Liquid TEA-TEB
- Mars Sample Return MMOD Protection
- Energy Modulator Webbing Shredding Testing
- Test and Modeling to Predict Spacesuit Water Membrane Evaporator Failures
- MAV Buffet/Aeroacoustics Numerical Simulations
- MPCV COPV Damage Tolerance Life by Analysis Risk Assessment
- Fire Cartridge Failure Investigation, Manufacturing, and Hardware Verification
- Evaluation of Alternate Helium Pressure Control Component
- Ti-NTO Compatibility Cross-Program Impact and Lessons Learned
- Tube Test Coupon for COPV Mechanics
- Issues with Qualification of Radiographic NDE Techniques
- Occupant Protection Testing
- Orion, NDSB2, and Gateway Material Electrical Properties
- 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 and Vendor Packing/Rigging Activities
- Southern Hemisphere Meteoroid Environment Measurements
- Orion Titanium Hydrazine Tank Weld - Environmentally Assisted Cracking
- CPV Working Group
- Independent Modeling and Simulation for CCP EDL
- SLS Aerosciences Independent Consultation and Review
- Reaction Wheel Performance for NASA Missions
- Exploration Systems Independent Modeling and Simulation
- Peer Review of the MPCV Aerodynamic/Aerothermal Database Models and Methods

AERONAUTICS

X-59 Fuel Tank Assessment

The NESC is assisting in the evaluation of risks associated with the installation and operation of strain gages in the fuel storage system on X-59 hardware. The work includes analysis, modeling, and the development of mitigation strategies.

NASA's X-59 quiet supersonic research aircraft sits on the ramp at Lockheed Martin Skunk Works in Palmdale, California.

Completed Technical Activities

CROSSCUTTING WORK

The NESC's crosscutting assessments have broad-Agency reach, the results of which can inform multiple programs, spacecraft, and missions.

Best Practices for Fabrication of Microelectronic Devices

Team included members from KSC, GSFC, MSFC, and Johns Hopkins University

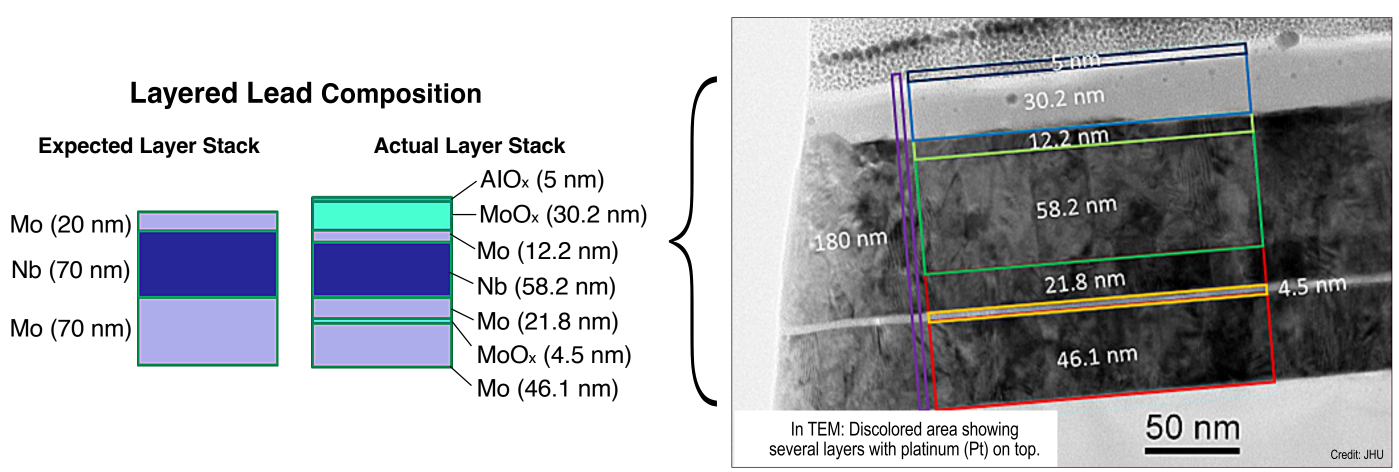
The space industry has been plagued for years by material degradation during the fabrication of microelectronic devices. Because the devices are created by layering dissimilar metals, there is a long history of metallic corrosion occurring at those interfaces. However, commonly used materials and systems are often overlooked as potential sources of this degradation. When these issues were observed in NASA devices, an NESC team of materials and electronics experts surveyed recent anomalies.

The team used multiple microscopy and spectroscopy techniques, two-wire resistance measurements, and electroanalysis to provide detailed imaging and compositional analyses of the affected devices. While there was no indication of galvanic corrosion at dissimilar metal interfaces, the team did detect the presence of metal oxides in the discolored regions and found the source of the oxidation and unexpected metals to be exposure to both deionized water and oxygen plasma and residual material in the fabrication chamber from previous use. The team's report provided recommendations for process control and reduction of contamination sources to improve the quality of future fabrication runs of these devices.

Refer to Technical Bulletin 23-07:

Best Practices for Fabrication of Microelectronic Devices

NASA.GOV/NESC



The NESC used transmission electron microscopy (TEM) to image the composition of a detector's superconducting leads. Above figures show the expected material layer stack and the actual layer stack from the cross-sectional analysis.

Monitoring and Predicting Meteor Showers for NASA Missions

Team included members from MSFC, GSFC, JPL, JSC, LaRC, and The Aerospace Corp.

NASA's ability to forecast meteor showers allows the Agency to protect its astronauts and assets from these events by using mitigating tactics such as delaying launches, avoiding ISS extravehicular activities, reorienting spacecraft, or phasing orbits to lessen or avoid their impact altogether. MSFC's meteoroid stream model forms the basis of these forecasts, which are used not only by NASA but also by commercial launch providers, the National Oceanographic and Atmospheric Administration, and the U.S. military.

This year the NESC completed an independent evaluation of the importance of preserving NASA's forecast and prediction capability for its existing assets as well as future missions. The team gathered data from programs and projects that have used forecasts in the past or may need it in the future and looked at NASA's meteoroid shower forecasting capability along with micrometeoroid and orbital debris risk assessments involving meteor showers or meteoroid streams.

The team found that quantification of potential risks and mitigation strategies were crucial to the success of NASA's Moon-to-Mars initiative as well as the sustainability of human exploration in low Earth orbit, cislunar space, and eventual crewed missions to Mars. In addition, several NASA assets from low Earth orbit to Mars (the James Webb and Hubble Space Telescopes, Chandra X-Ray Observatory, Mars Sample Return Campaign), as well as commercial assets such as Crew Dragon can and have benefited from meteoroid stream forecasting. Also, annual and episodic meteoroid stream analysis remains necessary because of inherent variability in meteor showers and the discovery of new streams and sources.

The Perseids Meteor Shower

Transitioning to Autonomous Flight Termination Systems

Team included members from GSFC, JSC, KSC, LaRC, and MSFC

Next generation flight termination systems (FTS) are transitioning from human-commanded to autonomous (AFTS) systems and are being progressively employed on board launch vehicles to replace ground personnel and infrastructure needed to destruct the vehicle should an anomaly occur. This automation uses onboard real-time data and encoded logic to determine if the flight should be self-terminated. For uncrewed launch vehicles, FTS systems are required to protect the public and are governed by the United States Space Force. For crewed missions, NASA human spaceflight (HSF) requirements augment range requirements to add crew safety into the design and to certify each flight according to human-rating standards. Similarly, crewed systems have additional unique needs to delay destruction for crew escape, alternative abort options, and possible crew awareness/override, which introduce additional requirements and integration complexities. The avionics, electrical, and software teams within the NESC have authored Technical Bulletins 23-02 and 24-02 summarizing key considerations and best practices for incorporating AFTS into human-rated systems. Key points from these publications are highlighted below. These teams are also working with HSF programs, including the Space Launch System, Commercial Crew Program, and launch vehicle providers to support incorporating the additional crewed requirements in their transition to crewed AFTS.

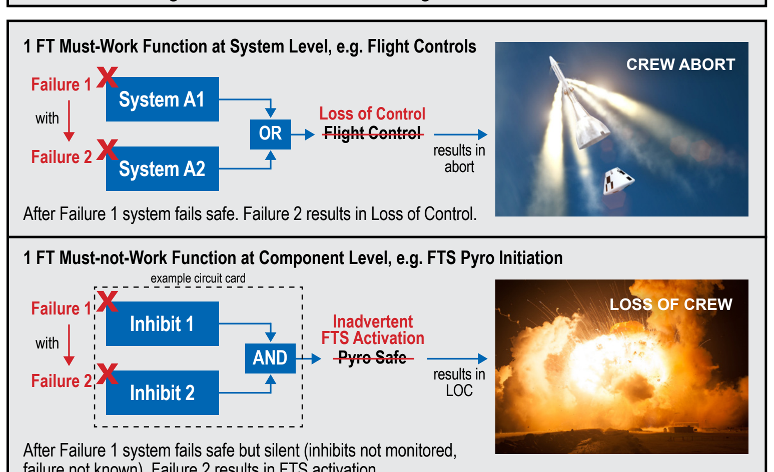
Software

- Develop software per NPR7150.2D as Class A Safety-Critical in addition to RCC 319-19, treating CASS as reuse and MDL as safety-critical.
- Incorporate software fault tolerance and prevention, including implementing monitoring systems and considering crew involvement and backups, as summarized in Technical Bulletin 23-06.
- Perform hazard analysis considering unique AFTS software risks, controlled with rigorous processes to assure software validity and integrity.
- Validate in test-like-you-fly computing environments with off-nominal scenarios.

Avionics/Electrical

- Implement an upstream Arm/Safe power inhibit switch with separate and independent control to electrically safe firing circuitry during crewed flight.
- Arm only when Fire is imminent.
- Provide dual-failure tolerance to failure modes that not only destroy the vehicle but preempt emergency systems intended to allow crew survival (e.g., ascent escape/abort).
- Develop a voting architecture or a watchdog monitor to address avionics hardware and some software failure modes.

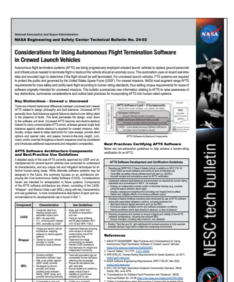
Human Rated Design Features Checklist to Prevent Inadvertent Fire
Arm only when Fire is imminent
Two-fault tolerance to inadvertent Fire by inspection
Physical design separation and independence of fault-tolerant strings
Isolation from other systems
Inhibit protections and monitoring
Independent monitoring of software functions
Activation margin controls internal to firing circuit



Refer to Technical Bulletin 23-02:

Safety Considerations when Repurposing Commercially Available Flight Termination Systems from Uncrewed to Crewed Launch Vehicles

NASA.GOV/NESC



Refer to Technical Bulletin 24-02:

Considerations for Using Autonomous Flight Termination Software in Crewed Launch Vehicles

NASA.GOV/NESC

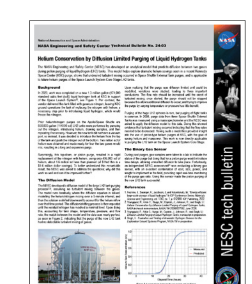
In 2023, teams at KSC completed work on the additional 1.3-million-gallon liquid hydrogen tank used for SLS propellant loading. The tank was delivered with gaseous nitrogen. One sensor tested was used for real time monitoring of the purge gas ratio (helium v. nitrogen) when the nitrogen was replaced with helium.

Sensors Identified to Monitor Hydrogen Operations in Anaerobic Conditions

Team included members from LaRC and KSC

The Exploration Ground Systems (EGS) Program at KSC needs anaerobic hydrogen sensors to quantify hydrogen concentrations in nitrogen or helium backgrounds. Gas monitoring is required for the safe handling of liquid and gaseous hydrogen and often includes an oxygen-free blanket purge around potential leak points using either nitrogen or helium. Monitoring in anaerobic conditions is challenging since the majority of hydrogen measurement techniques require some level of oxygen. Launch processing systems, for example, use commercially available hydrogen sensors that require air at the sensor for proper operation. Adding air to the sampled gas requires additional power, weight, and heat; adds to the footprint and cost of the system; and dilutes the sample, affecting the dynamic range, detection limit, and accuracy of the measurement.

This year the NESC completed work to evaluate and test anaerobic hydrogen sensors. The general testing procedure exposed the sensors to various concentrations of hydrogen in either nitrogen or helium. Testing measured sensor drift, lowest detectable concentration of hydrogen, linearity (up to 8.0% hydrogen), repeatability, and response time. The team identified three sensors observed to function in both nitrogen and helium backgrounds under anaerobic conditions, with one performing well enough to recommend for testing in existing ground support equipment. A second sensor was recommended for a different application and has already provided NASA with significant cost and schedule savings, noted in Technical Bulletin 24-03.



Refer to Technical Bulletin 24-03:

Helium Conservation by Diffusion Limited Purging of Liquid Hydrogen Tanks

NASA.GOV/NESC

Understanding COPV Stress Rupture and Reliability

Team included members from LaRC, JPL, GRC, MSFC, JSC, WSTF, and Virginia Tech

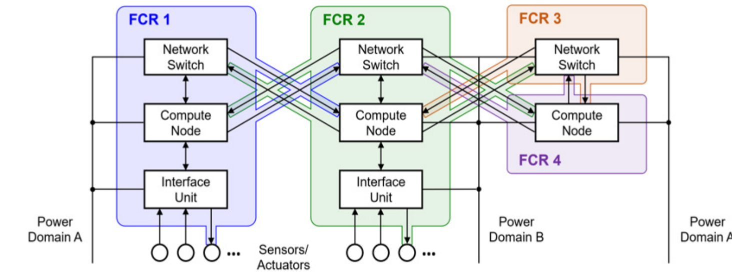
The NESC completed a decade-long study documenting composite overwrapped pressure vessel (COPV) reliability related to stress rupture. The NESC has invested significant time and resources to better understand how COPV's work, and more importantly, how these complex, high-pressure storage systems can fail. COPVs store propellants and life-support consumables on launch vehicles and spacecraft at high pressures, and failures have the potential to be catastrophic for the crew and mission. The work focused on acquiring strand stress-rupture data to develop a global stress rupture model, supplement small-scale COPV tests completed by ISS, and obtain sufficient data to provide an understanding of stress rupture in carbon fiber strands.

The report documents issues the team faced with data acquisition, results interpretation, and model development. And it also provides a novel statistical assessment based on strand and overall vessel strength distributions showing strand strength cannot be used to predict vessel performance and that quantitative reliability for COPVs cannot be determined. A phenomenological model was developed to demonstrate qualitatively that vessels maintained at operational pressures below proof are unlikely to experience stress rupture. Based on the results of this study, the NESC provided recommendations for future situations where stress-rupture reliability estimation is required (e.g., for new COPV designs including new material systems and/or fabrication techniques) or to increase reliability of existing vessel designs.

To gather strand stress rupture data, a team at MSFC fabricated strand specimens by impregnating carbon fibers with resin, threading them through shrink-fit tubing, and curing them in an oven (a). At LaRC, grips were applied and the strands (b), and completed test specimens were tested at WSTF (c).

Designing Failure-Tolerant Avionics for Human Spaceflight

Team included members from LaRC and JSC



An example of fault containment regions (FCR) in a failure-tolerant avionics system as shown in the Best Practices Guidelines. Wires within communication links are typically mapped to FCRs based on the direction/source of the traffic flow.

In a crewed spacecraft, the avionics system performs a variety of safety-critical functions, such as controlling the position and attitude of the vehicle in space, detecting on-board failures and performing autonomous recovery operations, activating parachutes and abort systems, and relaying commands from ground operators to the vehicle. Any loss or incorrect performance of these functions can be catastrophic, which is why these systems are required to meet much more stringent failure tolerance and reliability requirements than those for uncrewed vehicles. Moreover, the burden of proof for showing these requirements are met is significantly higher. Unfortunately, it is not always clear to designers what steps are needed to mature and demonstrate a sufficient avionics architecture for human spaceflight. This year the NESC Avionics Technical Discipline Team developed recommended best practices that provide an overview of some of the major steps needed to mature and justify the design of an avionics system for crewed spacecraft. The study focuses on many aspects of the avionics system including flight computers, onboard data networks, remote interface units, and sensor and actuator interfaces and is intended as a reference for avionics designers, reliability engineers, and program managers to help ensure crew safety and mission success. While the study focuses on crewed spaceflight, the core process described may also be applicable to flagship uncrewed missions. NASA/TM-20240009366.

A Framework for Fracture-Critical Parts

Team included members from LaRC, MSFC, JSC, GRC, KSC, and JPL

The use of additive manufacturing (AM) to build spaceflight hardware offers flexibility that can result in highly efficient designs. However, these designs typically have a higher rate of flaw introduction than with traditional manufacturing methods and may also have regions that cannot be fully inspected for flaws. The result is an increase in the risk of failure from an undetected crack or defect. And in fracture-critical components, the consequences of failure could be catastrophic. Since full inspection using standard nondestructive evaluation—commonly used for flaw and defect screening—is not possible for some of these parts, an alternative approach will be needed to certify AM fracture-critical components for use in human-rated applications. To develop a framework for general certification and approaches for risk evaluation, the NESC led the Agency AM Certification Support Team (AACT).

The AACT recently completed the first of three risk-reduction projects, one of which was aimed at helping NASA understand and characterize AM process-sensitive defects. The NESC catalogued and assessed the physical causes and characteristics of AM defects, focusing on a laser powder-bed fusion process, which is currently the most advanced for production of critical hardware (though the report's conclusions are broadly applicable to other AM process categories). The team also investigated methods to define rates of occurrence as a function of size for inherent defects and evaluate the defect state throughout the AM process window. Two additional AM risk-reduction projects are currently in work to address in situ monitoring and metallurgy. The NESC also led development of the Agency AM standards referenced below.

AM enables complex designs that were previously impractical or impossible to manufacture, but some parts will be challenging to reliably inspect per fracture control requirements.

References:

1. NESC/TM-20240002004 Agency Additive Manufacturing (AM) Certification Support Team (AACT) Risk Reduction - Safe Life Category: Fracture Control Framework for Un-inspectable Fracture Critical AM Parts
2. NASA-STD-6030, AM Requirements for Spaceflight Systems
3. NASA-STD-6033, AM Requirements for Equipment and Facility Control

Completed Technical Activities

ESDMD DESIGNS & INTEGRATION

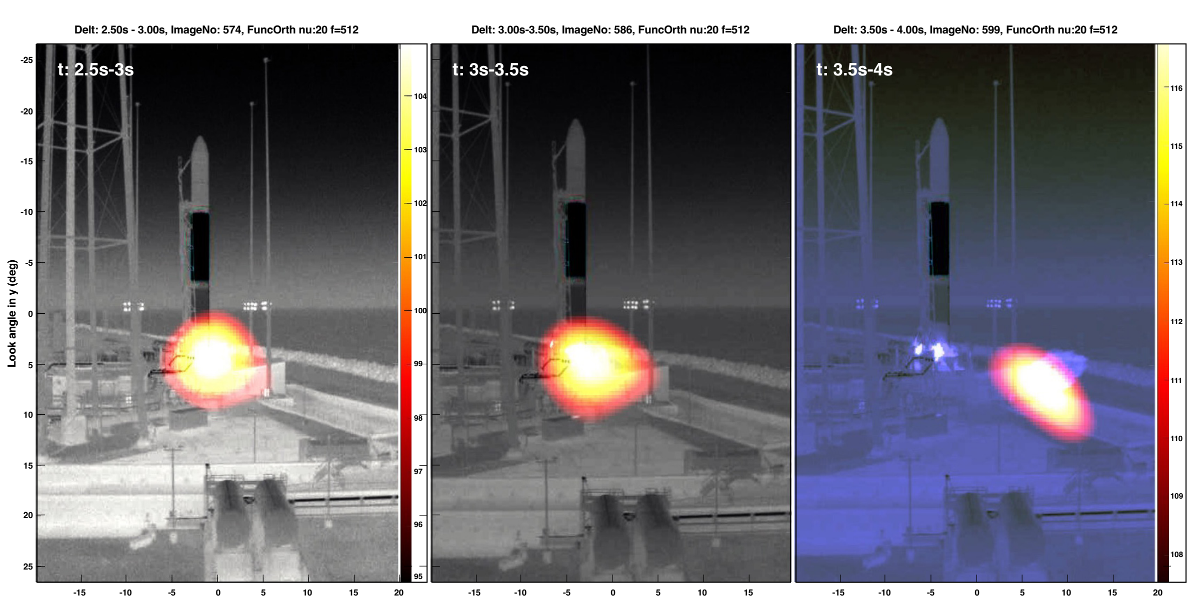
The NESC continues to support the Artemis Program and its elements—the Orion MPCV, SLS, and EGS Programs—as well as Gateway and other work in support of NASA's return to the Moon and long-duration missions to Mars.

Identifying Noise Sources During Launch

Team included members from ARC, JSC, KSC, SSC, LaRC, WFF, and GRC

All parts of a launch vehicle, launch pad, and ground support equipment are subjected to high acoustic loads generated during lift-off. To suppress this acoustic environment, measures are employed including damping with a water deluge system and diverting engine plumes away from the vehicle via flame trenches. Even a single decibel reduction of the acoustic levels can translate into a sizable reduction of acoustic loadings, certification needs, operational costs, and even vehicle weight, so lowering the acoustic level is an important aspect of launch-pad design.

In 2011 and 2012, the NESC sponsored research into the effectiveness of a microphone phased array (MPA) to identify noise sources and tested the array during an Antares launch from WFF. This simple prototype array was able to identify noise sources, including those related to exhaust plume impingement on pad structures during the launch. Building on that previous work, an open-space truss MPA architecture was developed, which produced a much cleaner image of noise sources emanating from the vehicle and reflected off of launch pad structures. The system was tested during a static-fire engine test at SSC as well as during the NG-19 Antares launch from WFF in July 2023. The array was able to collect meaningful data under acoustic conditions similar to those expected during the Artemis II launch. Next, the MPA will be deployed at KSC for the Artemis II launch to measure the acoustic environment and identify critical noise sources during that event. The data collected will help further refine and optimize the sound suppression systems for Artemis III and future launches.



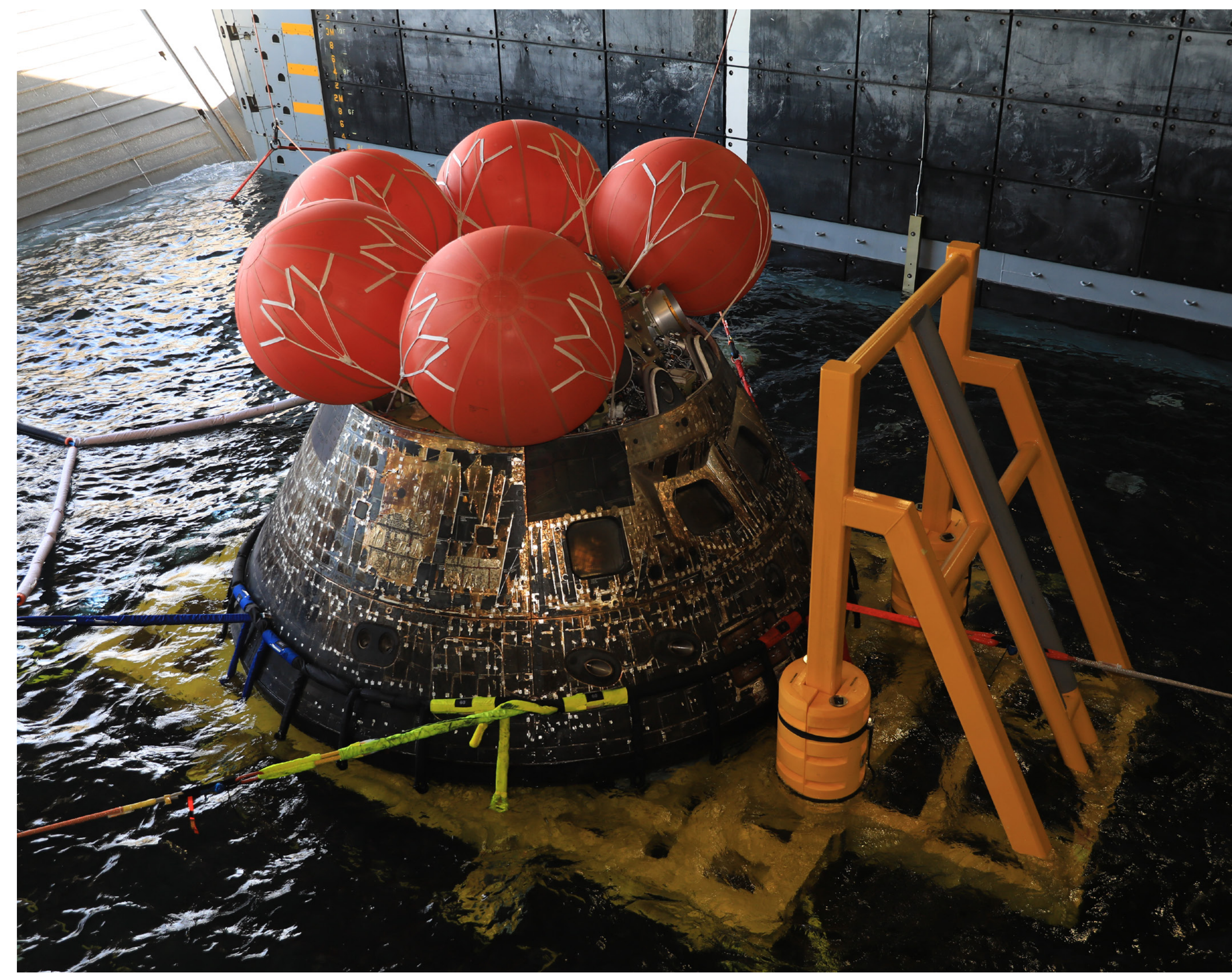
Time evolution of noise generation during the NG-19 launch. The acoustic intensity of the redirected flow from the flame trench opening evolves to become a much stronger noise source, while acoustics from the plume are effectively mitigated by the sound suppression on the launch pad surface.

NESC Support for MPCV Orion CMUS Hydrodynamics

Team included members from KSC, JPL, MSFC, GRC, JSC, LaRC, Johns Hopkins Applied Physics Laboratory, National Renewable Energy Laboratory, and Applied Physical Sciences

Since 2018, the NESC has provided hydrodynamics, loads, and ocean engineering support for the Multi-Purpose Crew Vehicle (MPCV) Crew Module (CM) Uprighting System (CMUS) team. The CMUS is designed to upright the CM and maintain seakeeping for crew safety and capsule recovery in potentially adverse wind and wave conditions. The five self-inflating 55-inch-diameter CMUS bags that are attached to the CM with multiple tethers, must upright the CM within 4 minutes, provide 24-hour seakeeping, and ensure the loads on the CMUS bags and tether do not exceed capability.

The NESC's independent analysis, which concluded this year, focused on supporting the development, verification, and validation of dynamic models for analysis of CM and CMUS performance and loads in the open ocean. The assessment team provided assistance with concept of operations, wave-buoy deployment, and data post-processing for seakeeping and uprighting testing; completed Artemis I seakeeping and loads analyses; and developed dynamic simulations for intermediate uprighting orientations. They also provided rough order of magnitude tether loads predictions and development of a continuous multibody uprighting model with wave coupling and softgoods deformability, and leveraged this model to estimate dynamic loads in sea conditions outside of where test data exist.

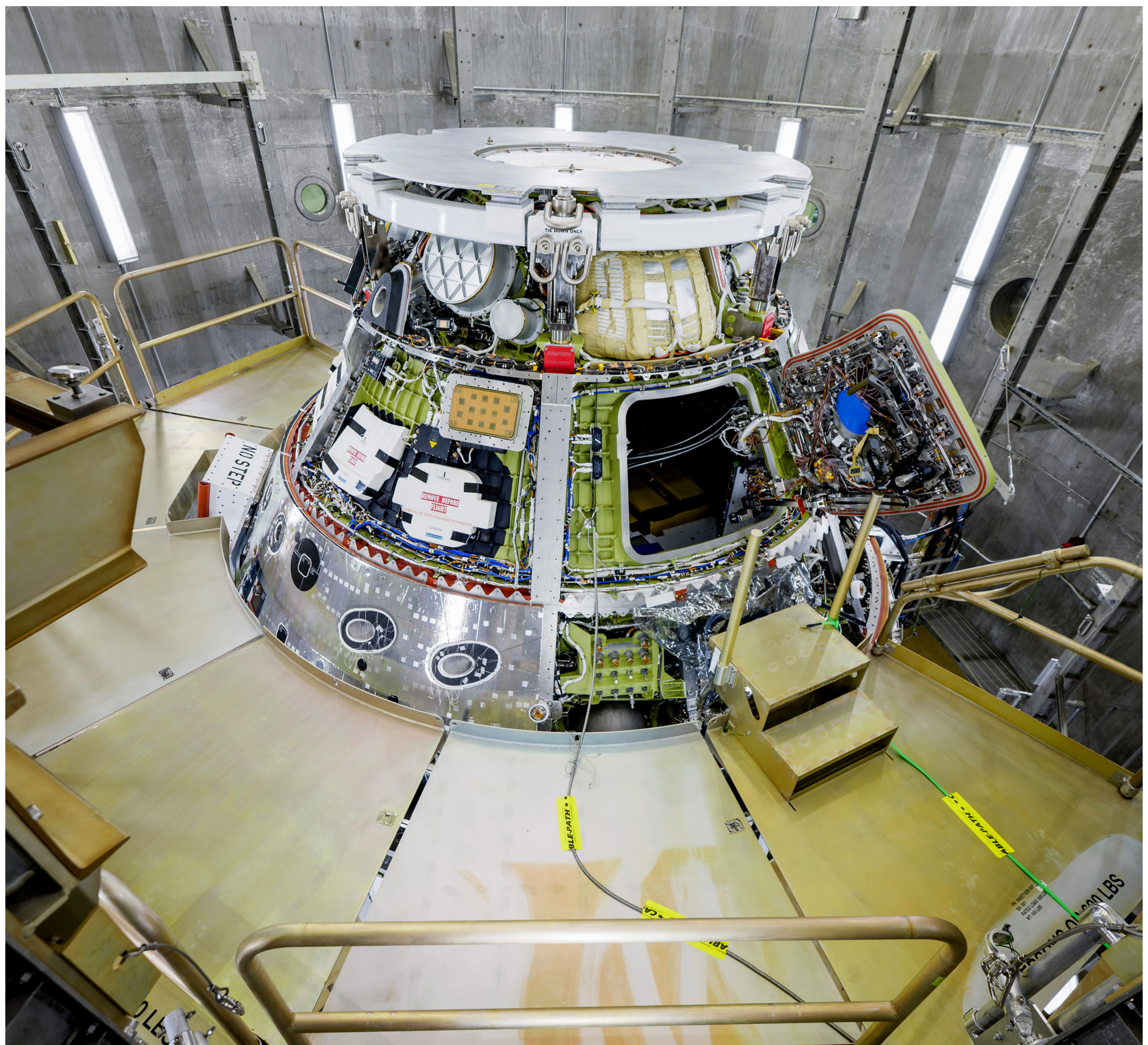


NASA's Orion spacecraft was recovered inside the well deck of the USS Portland following the Artemis I mission. The CM Uprighting System, self-inflating bags attached using multiple tethers, successfully deployed at splashdown.

Orion Side-Hatch Opening Delta Pressure Analysis and Correlation

Team included members from JSC, KSC, ARC, and GRC

The NESC completed a peer review of the Orion CM side hatch (SHCH) delta pressure test and instrumentation plan, Automated Dynamic Analysis of Mechanical Systems (ADAMS) multibody dynamics model, and delta pressure test data in preparation for upcoming testing and model correlation activities. The SHCH has requirements for a delta pressure between the CM interior and the external environment during opening, which are driven by potential pressure differentials during nominal operations (e.g., prelaunch cabin leak checks), emergency scenarios (e.g., capsule fire), and the estimated SHCH design capability. The NESC team also independently correlated the ADAMS model to the delta-pressure test results. The team found the general test approach to be sound for a model correlation activity of this complexity. They also identified best practices for consideration during testing and noted areas during the ADAMS model review that could improve modeling predictions.



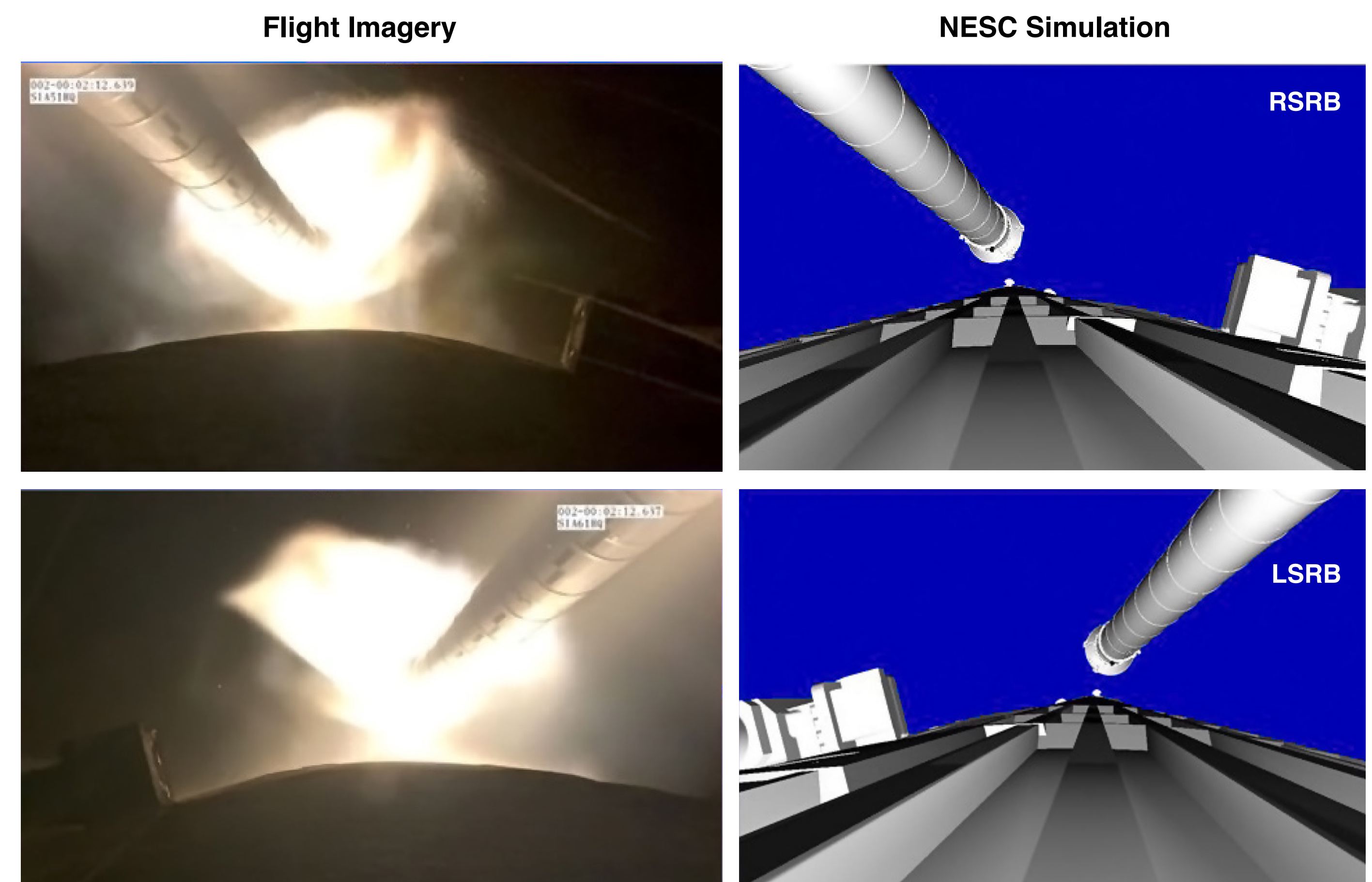
The NESC peer reviewed the Orion CM side hatch delta pressure test and instrumentation plan for the Moon-to-Mars Program. Pictured is the Artemis II Orion spacecraft during tests simulating deep space vacuum conditions in KSC's west altitude chamber in June 2024.

Independent Modeling and Simulation for Artemis

Team included members from KSC, LaRC, GRC, MSFC, ARC, and JSC

Most of NASA's human and robotic NASA flight programs have benefited from using independent system models and integrated simulations to identify and resolve highly coupled system failure modes and technical risks, particularly those that occur at or near complex hardware, software, or discipline interfaces. More than a decade ago, the NESC began developing an independent modeling and simulation capability for what is now the Artemis Program. The idea was to address any program or cross-program issues with the SLS, Orion MPCV, and ESG Programs throughout their design, verification, and flight readiness cycles. Over the years, the Exploration Systems Independent Modeling and Simulation (ESIMS) assessment team has used a flight-simulation-based approach to assess vehicle performance, critical separation events along the evolving Artemis I mission trajectory, and disposal analyses. Using the Program to Optimize Simulated Trajectories II, the team incorporates program-provided models into an integrated trajectory simulation that is capable of modeling multiple bodies simultaneously. Results from the trajectory simulation are then transferred to the Exploration Visualization Environment (EVE) tool for proximity analyses between the launch vehicle and the mobile launcher and clearance between the vehicle components during separation events.

In 2024, the ESIMS team closed out its Artemis I effort with the analysis of the mission's postflight data, comparing to preflight predictions using photogrammetry data and the Artemis Program's best estimate of trajectory, and using flight video to qualitatively assess vehicle dynamics. The analysis results included high-fidelity ascent modeling of lift-off clearance, solid rocket booster (SRB) separation, service module panel jettison, and other separation events, and modeling of stage disposal and debris splashdown. In 2024 the team also produced results for Artemis II high-fidelity modeling of ascent, lift-off clearance analysis, and booster separation and clearance analysis as well as Artemis IV ascent modeling, universal stage adapter separation and clearance, and co-manifested payload separation analyses. The team continues to actively work on high-fidelity simulation development, separation, and disposal analyses for Artemis missions II to IV (both SLS Block I and Block 1B).



These figures compare frames from the NESC simulation to the Artemis I flight imagery at 1.86 seconds after SRB separation, when the near-field separation clearances are critical. Analysis results supported the SLS Program's conclusion that the SRB separation event was nominal and separation clearances were as expected.

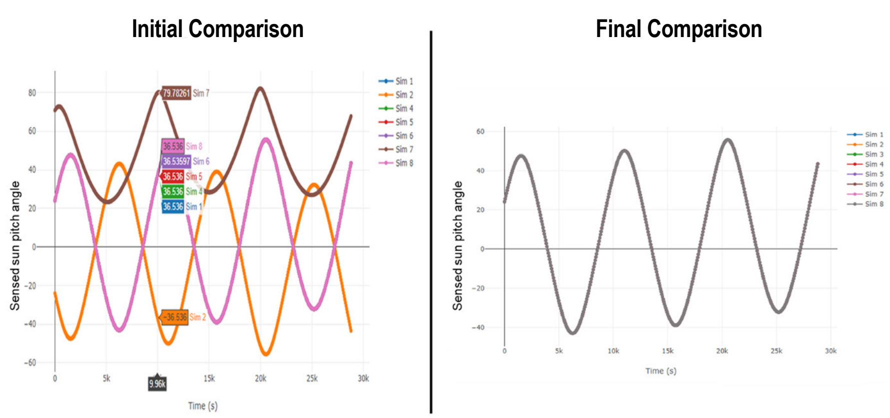
Expansion of Check-Cases for Lunar Exploration

Team included members from MSFC, LaRC, KSC, JSC, ARC, JPL, and GRC

Many of NASA's centers have independently developed preferred frameworks for flight-simulation software, and differences in model implementation and numerical approaches have resulted in variations between simulations and analyses. In 2015, the NESC released benchmark Earth-based check-cases for well specified, rigid-body, six-degree-of-freedom aerodynamic and spacecraft models to promote consistent and accurate flight simulations across multiple Agency tools and facilities.

Recently, the NESC expanded that effort to add lunar-based check-cases to support new lunar exploration initiatives as more companies are providing services for NASA in the cislunar region and at the Moon. Validated simulations will be crucial to understanding the analyses used to meet requirements. This study produced a smaller, focused set of cases that exercise new and unique features of the lunar environment in comparison with eight high-fidelity NASA simulation tools and provides a measure of validation for simulations supporting Human Landing Systems. All simulation output data, check-case descriptions, and an interactive webtool are now hosted on an NESC Academy site. This allows external simulation developers to upload simulation data for comparison against this set.

Example Comparisons: Case 5 High Lunar Orbit
Sun Pointing Angle (Pitch Component) Regarding Vehicle Frame

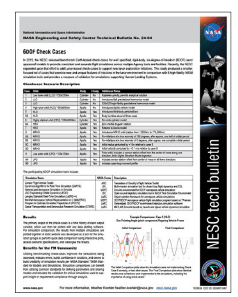


The Initial Comparison plots show the simulations were not implementing Check Case 5 correctly, or had other issues. The Final Comparison plots show identical results once corrections were implemented to the simulations, indicating the importance of using check cases.

Refer to Technical Bulletin 24-04:

6-DOF Check Cases

NASA.GOV/NESC



https://nescacademy.nasa.gov/flightsim

Case	Orbit	Body	3-body	Additional Notes
1	Low lunar orbit (LLO) ~120x120km	Cylinder	No	Keplerian gravity, permits analytical solution
2	LLO	Cylinder	No	Introduces 8x8 gravitational harmonics model
3	LLO	Cylinder	No	320x320 high-fidelity gravitational harmonics model
4	High lunar orbit (HLO) ~500x500km	Apollo	No	Introduces Apollo vehicle model
5	HLO	Apollo	Yes	Introduces third-body perturbations
5A	HLO	Apollo	Yes	Body tumbles about all three axes
6	Highly eliptical orbit (HEO) ~250x9385km	Cylinder	Yes	Re-visits cylinder model
6A	HEO	Cylinder	Yes	Zero inertial angular rotation
7	HEO	Apollo	Yes	Returns to Apollo model
8	NRHO	Apollo	Yes	Introduces NRHO orbit (radius from ~2000km to ~70,000km)
8A	NRHO	Apollo	Yes	Re-initializes at a true anomaly of 180 degrees, after approx. one half of orbital period
8B	NRHO	Apollo	Yes	Re-initializes at a true anomaly of 0 degrees, after approx. one complete orbital period
8C	NRHO	Apollo	Yes	Initial radius perturbed by +10m relative to case 8
8D	NRHO	Apollo	Yes	Initial velocity perturbed by +0.1 m/s relative to case 8
9	Low polar orbit (LPO) ~120x120km	Apollo	Yes	Polar orbit, includes a sensor station offset from the center of mass along one direction; tests Digital Elevation Model ingestion
9A	LPO	Apollo	Yes	Includes sensor station offset from center of mass in all three directions
9B	LPO	Apollo	Yes	Includes open-loop moment profile

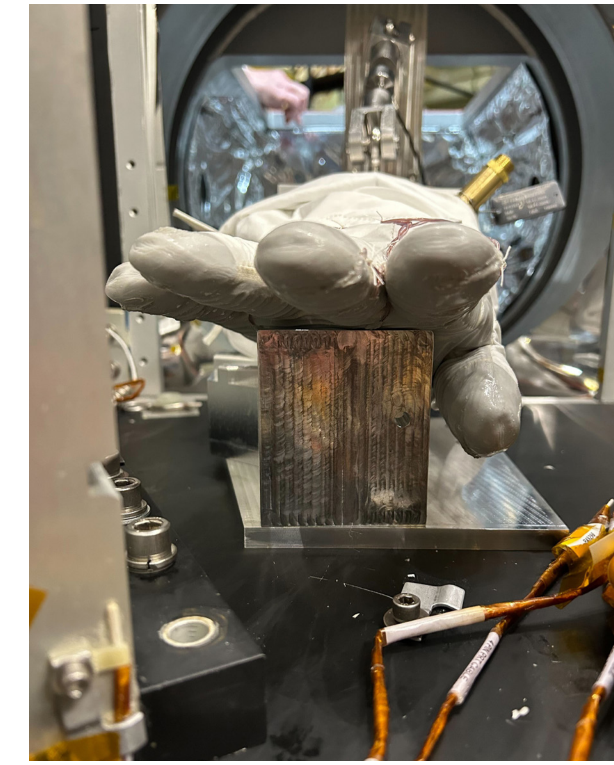
This table summarizes the lunar check-case scenarios, starting from a simple Keplerian low lunar orbit, then adding effects, such as a detailed gravitational field and third-body perturbations. Vehicle models include a simple cylinder that tests basic rotational dynamics and modeling and the Apollo spacecraft for more complex dynamics.

Evaluating Candidate Spacesuit Gloves and Materials

Team included members from MSFC, JSC, JPL, Wells Lamont Industrial, and North Carolina State University

The Artemis spacesuit glove will be the first line of protection used to shield a crewmember's hands from environments during extravehicular activity. As Artemis missions will include more extreme environments than those experienced on the ISS, the development, verification, and validation of gloves for the lunar environment pose three key challenges: there are no standardized tests defined to evaluate glove durability, particularly in permanently shadowed regions on the Moon; there are insufficient data on glove performance in a lunar environment from which to compare new designs; and ISS glove fabrics are unlikely to be sufficient to meet lunar environment requirements.

Existing Phase VI Exploration Extravehicular Mobility Unit gloves were not designed for the lunar surface, and their use poses several safety and performance risks including durability and thermal protection against lunar loads and dust infiltration. This year, the NESC completed an activity to assess these risks, identify material alternatives, and develop several effective methods of screening candidate spacesuit glove materials. These methods include test processes for abrasion, tensile strength, elongation, and puncture and cut resistance. Additionally, a thermal test was developed to evaluate the glove thermal performance in the Artemis environment. As part of this effort, three new American Standard Test Method (ASTM) standards for the F47 Commercial Spaceflight committee have been submitted to evaluate and compare performance of suit gloves in critical areas for upcoming human spaceflight missions.



Glove testing was conducted in JPL's Cryogenic Ice Transfer, Acquisition Development, and Excavation Laboratory (CITADEL) thermal vacuum chamber using Phase VI gloves with a custom thermal manikin hand inside. The thermal vacuum chamber was conditioned to various descending temperatures down to 48 K. Here the glove touches a cold object.

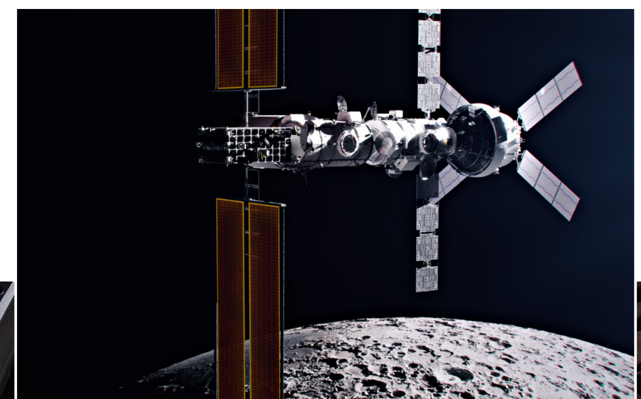
Artist's illustration of two suited crew members work on the lunar surface.

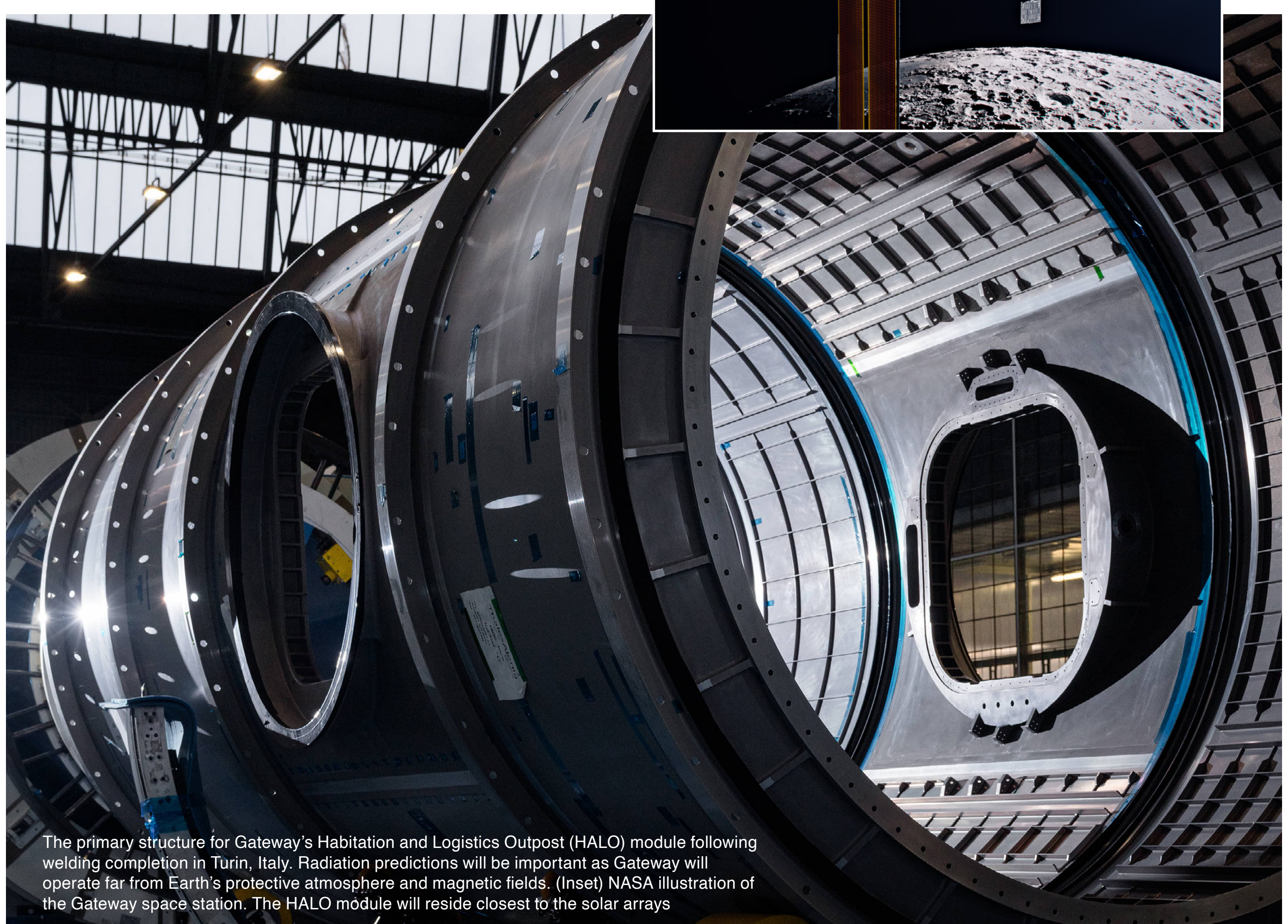
Evaluating Radiation-Analysis Tools

Team included members from MSFC, JPL, JSC, LaRC, GSFC, KSC, National Institute for Standards and Technology, ESA, Peraton, Experimental & Mathematical Physics Consultants, Sandia National Laboratories, Jefferson National Accelerator Facility, European Organization for Nuclear Research, and University of Tennessee

NASA's spacecraft-design community uses radiation-transport codes or radiation-analysis tools to estimate local radiation levels. The tool, SHIELDOSE-2 (SD2), has been commonly used in early spacecraft design to predict space-shielding radiation dose on materials. Understanding SD2's accuracy and range of applicability is important for NASA programs like Artemis, Gateway, and the Human Landing System. As important is knowing what tools are available when SD2 is not applicable.

To address questions about SD2's capabilities and limitations, the NESC performed as phase 1 a comprehensive review of SD2 documents and related references, examined SD2 assumptions when estimating doses in various detector materials, and conducted first-order simulations to understand the effect of typical density scaling for materials other than aluminum. In phase 2, the NESC team performed comprehensive comparisons between SD2 and other widely used radiation transport codes, with simulations to benchmark more complex non-Monte Carlo and Monte Carlo radiation-analysis codes. The results were used to create a database for various codes' predictive capabilities compared to other codes. The results demonstrated that SD2 can be used for aluminum thinner than 0.001 mm and determined SD2 density scaling should not be used for material thicknesses greater than ~0.5 mm. Results are available in NASA/TM-20230010640 (phase 1) and NASA/TM-20240012725 (phase 2).



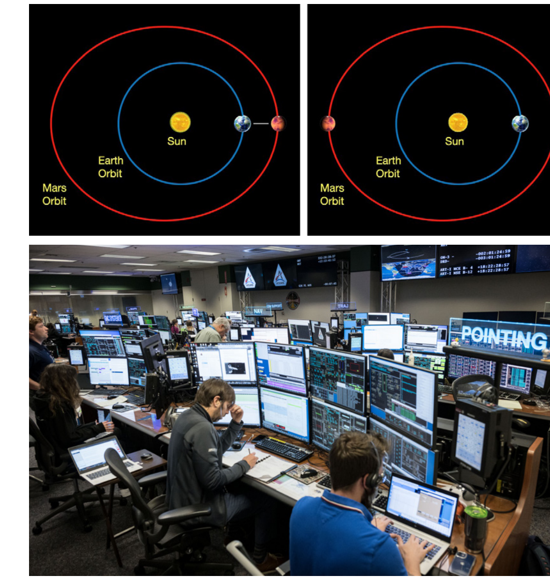


The primary structure for Gateway's Habitation and Logistics Outpost (HALO) module following welding completion in Turin, Italy. Radiation predictions will be important as Gateway will operate far from Earth's protective atmosphere and magnetic fields. (Inset) NASA illustration of the Gateway space station. The HALO module will reside closest to the solar arrays

Trade Space Analysis: Balancing Crew & Mission Design Parameters

Team included members from JSC, ARC, LaRC, GSFC, Huntington Ingalls Industries, The Aerospace Corp., KBR Wyle Services, and the U.S. Navy

Crewmembers on board NASA's human spaceflight missions rely on flight directors, flight controllers, and engineers in mission control for real-time support. Crew on a Mars mission, however, will not have that real-time support because of distance-induced communication delays (up to ~22 minutes one-way) and a continuous blackout period with Earth during superior conjunction (up to ~3 weeks for each mission). This fundamental constraint, which is unprecedented in the history of human spaceflight, brings a new appreciation for what the term "crew" encompasses. A Mars crew making real-time decisions about how to accomplish primary mission objectives and respond to unforeseen, time-critical failures will have to rely on their own knowledge assisted by decision-support systems, whose information would be limited to scenarios that were anticipated before the mission. In the past, crew size determinations have been based on a limited, mostly nonquantitative understanding of the impact of crew workload on mission success and crew survival. To give decision makers a tool for conducting trade studies and weighing whether a given crew size is adequate, the NESC developed a quantitative approach for determining crew size based on human performance modeling. The resulting report documents the methodology and evaluation framework; human performance models that output workload and expertise based on select Mars mission use cases; and trade-space analysis examples of crew complements built on modeling results. The NESC's quantitative methodology fills a longstanding gap in the tools for designing Mars missions. NASA/TM-20240011265.

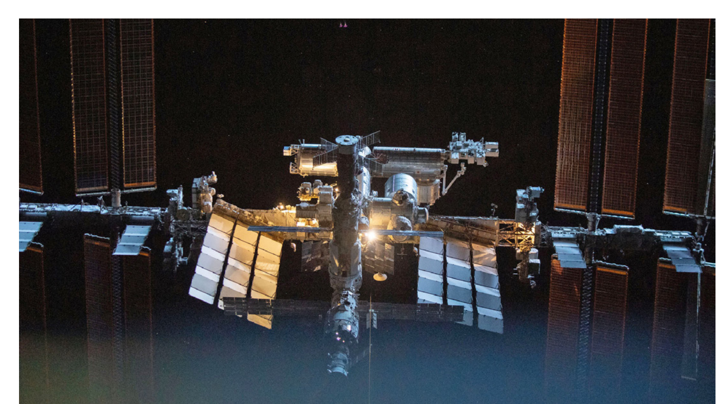


Top: NASA Mars missions have a moratorium on sending commands to spacecraft on the surface of Mars or in orbit around Mars during Mars solar conjunction. Bottom: Flight controllers observe the Orion spacecraft during the Artemis I mission. Mars crews will not always have real-time support from mission control.

Completed Technical Activities

SUSTAINING ISS

The NESC supports the Agency's maintenance of ISS as a major science platform, docking station for visiting vehicles, and temporary home to NASA's astronauts.



The International Space Station

The NESC assisted the ISS Program this year, providing expertise in materials, contamination, and space environments to support their investigation of a coolant leak as well as expertise in stress analysis, materials, additive manufacturing, and nondestructive evaluation for their evaluation of an emergency mask assembly. NESC teams also provided nondestructive analysis, materials, structures, and fracture control support in the development of verification and compliance approaches for a new urine pretreat tank design.

Completed Technical Activities

CCP INSIGHT

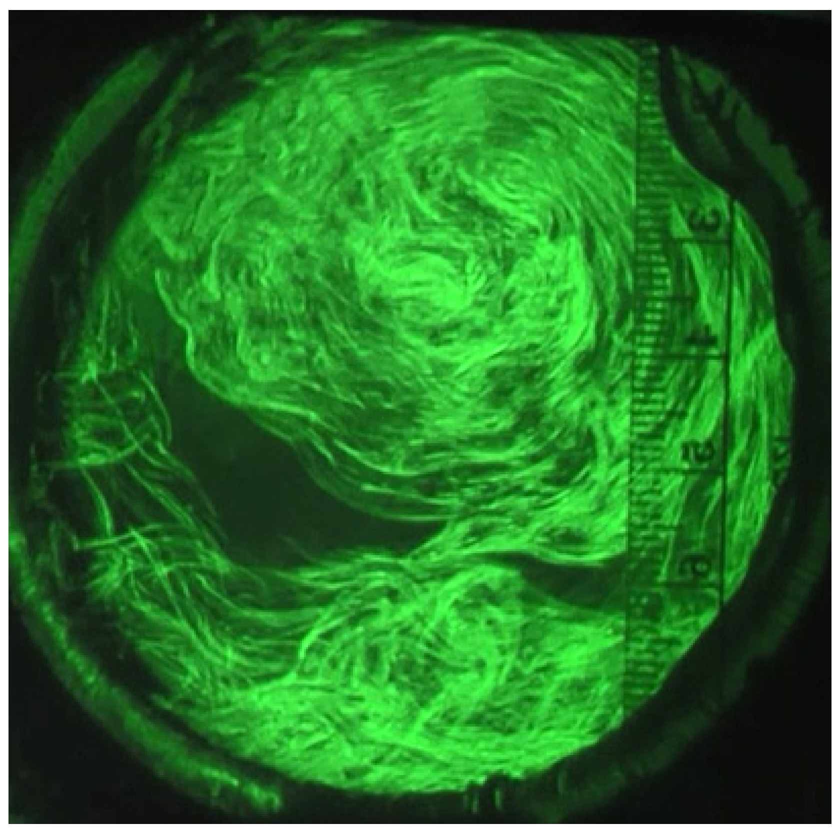
NESC assessments assist the Commercial Crew Program in the resolution of technical challenges encountered during the design, development, and flight of commercial spacecraft and launch vehicles.

Assessing Risks of Emerging Launch Vehicle Propellants

Team included members from GRC, JPL, JSC, KSC, LaRC, MSFC, SSC, WSTF, U.S. Army, U.S. Space Force, FAA, and involved commercial provider liaisons

Numerous launch service providers are developing or operating vehicles that use liquid oxygen (LOX) combined with methane or liquified natural gas (LNG) as propellants. These propellants provide high specific impulse but are also appealing as methane can be synthesized off-Earth, and the boiling points (BP) of LNG and methane are much higher and therefore more manageable than liquid hydrogen (LH2). These advantages opened the engineering design space to more capable (primarily lighter), reusable, and inexpensive launch and excursion vehicles.

These advantages, however, come with new hazards that need to be understood to design effective engineering and operational hazard controls. For example, the similarity in BP allows for less insulation and placing fuel and oxidizer in closer proximity on the vehicle. This gives rise to new failure modes that could lead to propellant mixing. Currently, the ignition and explosion characteristics of LOX/methane are not well understood in contrast to LOX/LH2 and LOX/RP-1. The hazard is complicated by the miscibility of LNG in LOX (RP-1 and LH2 are not miscible in LOX); the two can mix completely, regardless of proportions, forming a homogeneous, detonable solution. This mixing can result in a condensed-phase explosive known as MOX.



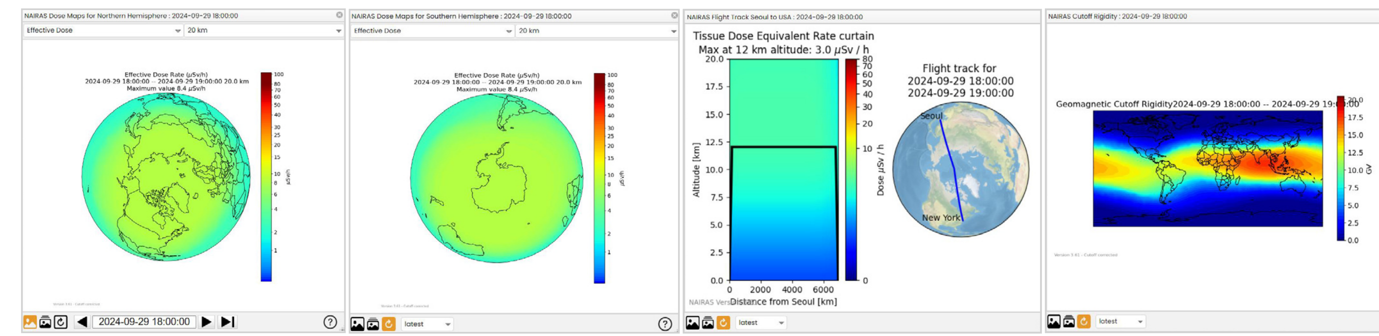
Using Schlieren imagery, a photography technique that captures fluid flow, testers simulated the LOX/LNG density gradient using a sugar-water/water mixture.

To understand the risks associated with LOX/LNG and LOX/methane, the NESC worked with an interagency group to develop tests and analyses to understand how vehicle designs and ground operations would contribute to or control specific hazards to protect the public, ground personnel, crew, payloads, and critical infrastructure. This knowledge is critical to inform risk decisions for launch facility siting, payloads, range and crew safety, and protecting the public. The NESC plan incorporated work already being pursued by industry and other government agencies, including the Federal Aviation Administration (FAA) and U.S. Space Force. The NESC crafted recommendations for current and future explosive-measurement projects and testing.

Radiation Environment Model Updates

Team included members from LaRC, JPL, GSFC, MSFC, and KSC

A new version, 3.0, of the Nowcast of Atmospheric Ionizing Radiation System (NAIRAS) radiation environment model, originally developed for computing the radiation dose for aviation flight crews, will now provide reference radiation environments for CCP flights. Flight data from radiation sensors have not always been available for CCP vehicles, so an alternative approach using space weather tools was required to provide the environments for post flight analysis. NAIRAS uses real-time measurements from satellites and space and terrestrial environment data to predict radiation exposure from cosmic rays and solar particles within Earth's radiation shielding. An NESC assessment team implemented NAIRAS at GSFC's Community Coordinated Modeling Center and modified the software to give tailored output in formats required for CCP contractor radiation analysis tools. Total ionizing dose and single event effects rates computed from NAIRAS can be compared to observations during flight to better understand CCP avionics performance in the flight environment and support validation of the radiation design methodologies. The development of NAIRAS 3.0 also led to significant model accuracy improvements, revealed new insights into the space radiation environment, and expanded the applications and user base of the model.



Screenshots of NAIRAS real-time graphical products: Northern hemisphere effective dose rate; southern hemisphere effective dose rate; vertical geomagnetic cutoff rigidity; and vertical slice of dose equivalent rate for a high-latitude commercial flight from New York to Seoul.

Completed Technical Activities

AERONAUTICS

The NESC has supported many of NASA's aeronautics programs such as X-planes with design consultations, risk assessments, anomaly resolutions, trade studies, and gap analysis.

NASA's WB-57

In support of the Aeronautics Research Mission Directorate, the NESC provided mechanical systems support and engineering consultation for an evaluation of gears used in the WB-57 pitch trim acuator to assist in decisions regarding overhaul and replacement. The WB-57 aircraft, based near JSC, fly research missions for the scientific community with its extended operation time and ability to fly at altitudes from sea level to more than 60,000 feet. The NESC Mechanical Systems TDT also helped assess the X-57 electric cruise motor system, providing feedback and advice on potential risk considerations.

Completed Technical Activities

SCIENCE

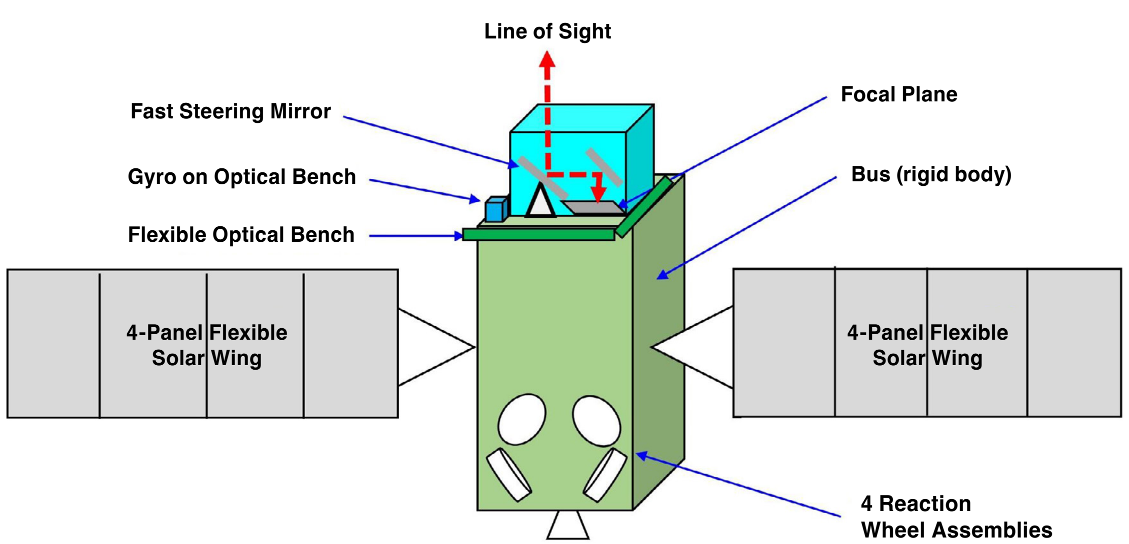
The NESC's first assessment was for NASA's CALIPSO in 2003. Since then the NESC has supported many robotic missions.

Precision Pointing Benchmark Problem for Next Generation Space Observatories

Team included members from KSC, JSC, LaRC, Johns Hopkins Applied Physical Laboratory, and The Aerospace Corp.

Since the mid-1980s, NASA has launched several first-generation spacecraft observatories with the optical instrument payload mounted on top of a large flexible structure. This configuration led to challenging control-structure interaction (CSI) problems. In recent years, however, control challenges have shifted from CSI to line-of-sight (LOS) precision pointing as designs have eliminated the large structure interface by mounting the optical payload directly on top of a relatively rigid spacecraft bus platform. As a result, the community's primary engineering challenge now focuses on achieving accurate LOS pointing at the payload level, with maximum rejection of underlying disturbances. One way to facilitate development of novel pointing control methods is to provide a benchmark problem for researchers that allows for the evaluation of proposed algorithms within a common framework. While a few benchmark problems exist with a focus on CSI applications, a new benchmark problem was needed to address LOS precision pointing with the next generation observatories.

To address this issue, the NESC, in collaboration with The Aerospace Corporation, developed a next generation space observatory benchmark problem. This will allow researchers to develop LOS pointing and disturbance-rejection solutions, implement the advanced control techniques on a realistic space observatory model, and compare results with alternative solutions. The NESC team worked to ensure that the problem was sufficiently realistic and challenging to inspire researchers to create innovative design solutions. NASA/TM-20240007117.



Elements of the Benchmark Space Observatory

The benchmark space observatory model comprises a bus and steerable optical payload; realistic disturbance environment; uncertainties including variable mass properties and variable flexible-body dynamics variations; adaptations for degraded sensors and actuators; and the capability to use the NESC jitter analysis toolbox to generate and evaluate standard jitter metrics.

Modeling MSR Orbiting Sample Behavior

Team included members from LaRC, GRC, and Applied Structural Dynamics

One of the key operations of the Mars Sample Return (MSR) campaign will be capturing the vessel containing those samples and preparing it for return to Earth. In early MSR design concepts, the Orbiting Sample (OS) would be caught by the Capture, Containment, and Recovery System (CCRS) inside its capture cone. Because it will be in mircrogravity, the OS would rebound inside the cone before placed into the Earth Entry System for transport. To verify the system would perform as expected, NASA would have to rely heavily on modeling since the operation cannot be tested completely like it would fly. After participating in several OS model peer reviews, the NESC was asked by the CCRS Project to perform a series of independent contact modeling simulations to verify and help define the Project's ADAMS contact modeling parameters. The NESC contact model was used to execute nonlinear dynamic contact simulations for four simple geometries to provide data that could be used by the CCRS team to define the free parameters for the Project's contact model. These data can be used to compare to results from mirrored simulations using ADAMS to refine parameters used for the capture and configuration simulations. NASA/TM-20230015574 and NASA/TM-20240007112.

Concept model of the lid and sample-holding tube for NASA's OS, which will hold tubes of Martian soil and atmosphere samples that will be returned to Earth through the MRS campaign. Credit: NASA/JPL-Caltech

Additional Completed Technical Activities

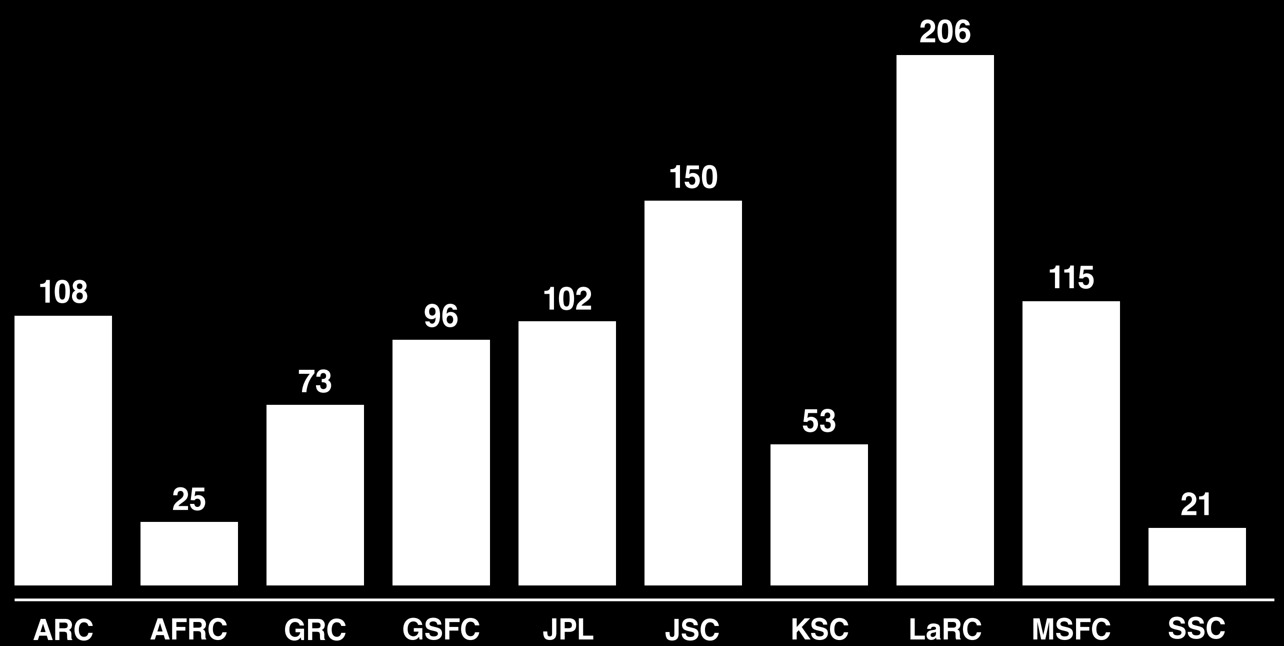
- CLARREO Pathfinder Radial Bearing Noise
- SLS Artemis II Delta DCR Review Support
- Sabatier Risk Mitigation Support
- Lunar Lander Assessment
- ISS MLM Coolant Leak
- ISS Emergency Mask Failure Investigation
- MSR EES Release Engineering Peer Review
- Orion Digital Motor Controller Investigation
- Rocket Lab Triboelectric Support
- Development of Optimal Slew Sequence to Calibrate ST-to-IMU Misalignment
- SLS Booster Design and Construction Standard Review
- Review of Next Gen Radioisotope Thermoelectric Generator Project Approach
- TEMPO Post Launch Acceptance Review Support
- Review Alternate Approach to NASA-STD-5020
- Roman Space Telescope Outer Barrel Assembly
- SLS B1B FSW CDR Review Team Support
- Evaluation of Dragonfly Replan Scenarios
- Tape Flammability Risk
- ISS Urine Pretreat Tank
- MEGANE Instrument Gamma-Ray Spectrometer
- Farside Seismic Suite Project Loop Heat Pipe
- WB-57 Actuator Gear Support
- X-57 Project
- MPCV Flywheel Exercise Device Acoustic Reduction
- SE&I Support to CCP Design Certification Review
- MPCV Power Distribution Unit
- Orion Mass Gauging Development Support
- Psyche Mission RAD750-V3
- OSAM-1 Assembly Joint Mechanism Test
- Contamination Control Consultant for Observatory
- EPIC/Athena Assessment Group
- NASA Quantum Sensing Capability
- Space Charging of Ocean Color Instrument Rotating Mechanism
- Methodologies for Determining VOD of Explosive Cords
- Erroneous Output Assessment Follow-on for Pacific Landings
- Gateway Level 2 CDR Review
- ISS Radiation Support
- GPS Anomaly
- Orion Separation Bolt Thermal Analysis
- Artemis I Acoustic and Blast Load Environments
- Lunar Flashlight Anomaly Support
- Independent M&S of MAV Ascent Phase of Flight
- Lunar Ground Testing Guidebook
- Space-Shielding Radiation Dosage Code Evaluation and Identification
- Exploration Systems Exterior Lighting Design Guidance
- MPCV Launch Abort Vehicle Powered Aero Database Development Using FUN3D
- CFD Assessment of AA-2 Axial Force Anomaly

949
EMPLOYEES
supported NESC work in FY24 from across all ten NASA centers.

NESC AT THE CENTERS

Meet the engineers and scientists who lend their expertise to NESC activities.

On the following pages, the NESC Chief Engineer at each NASA center spotlights some of the talented engineers and scientists who have participated in recent NESC assessments. Drawing on resources from across the Agency ensures that the technical challenge the NESC has been asked to address has the right team to solve it—not only the right expertise but the diversity of experience and unique perspective that each center employee brings to the problem.



949 Center Employees Supported NESC Work in FY24

AMES RESEARCH CENTER

108 ARC Employees Supported NESC Work in FY24

The Ames Research Center (ARC) provides a combination of engineering personnel, testing facilities, and computational resources to the NESC. Several of the NESC's most pressing assessments depended on ARC's world-class arc jet and advanced supercomputing facilities/expertise to formulate recommendations to the Agency on active human- and robotic-spaceflight missions. ARC personnel also were active in 19 NESC TDTs, and the NASA Technical Fellows for Aerosciences and Human Factors reside at ARC. Other staff supported NESC activities including Dragonfly Dynamic Stability, the DaVinci Mission, Balloon Program Quality Assurance Evaluation, Exploration Ground Systems Cryo Piping, and the Orion Crew Module Heatshield Char Investigation. This year's profiled individuals participated directly in these assessments and demonstrate the diversity of expertise present at ARC.

Dr. Donald R. Mendoza
NESC Chief Engineer

Dr. Brody Bessire

A member of ARC's Thermal Protection Materials Branch, Dr. Brody Bessire plays a crucial role in advancing materials development and modeling through the Entry Systems Modeling project. His research is focused on understanding the ablation mechanisms that control thermal protection systems (TPS) performance, exploring complex processes such as pyrolysis, gas-surface interactions, crack formation, and spallation. Dr. Bessire's expertise has been instrumental in the NESC's support of the Orion CM heatshield, where insights into the ablation mechanisms of Avcoat were achieved through a collaborative effort across NASA. "One of the greatest strengths of working with the NESC is their ability to bring together talent from across the Agency," he said. "Collaborating with NASA's exceptionally skilled professionals has deepened our understanding of TPS performance and paved the way for future TPS development."

Douglas Fraser

Mr. Douglas Fraser is the Pressure Systems Manager (PSM) in the System Safety and Mission Assurance Directorate, managing ARC's ground-based pressure system safety program. When the NESC requested support to resolve modeling and overstress issues in liquid hydrogen and liquid oxygen vacuum-jacketed supply piping, Mr. Fraser's pipe stress analysis software experience was invaluable. "I was able to recommend improvements to the modeling approach using more realistic structural stiffnesses that provided sufficient relief and redistribution of loads to resolve the most critical overstress issue. And I could confirm the appropriateness of the modeling techniques and analyses performed on the systems," he said. "An unexpected challenge on a new system is always exciting to an engineer, and the opportunity to help even in a small way on one of NASA's critical flight missions will be gratefully remembered by this PSM for a long time."

Dr. Peter Gage

Dr. Peter Gage works in systems engineering for the Ames Space Technologies Division, which focuses on TPS as well as atmospheric entry analysis and system design for entry vehicles. He is assisting the NESC with work on the Orion crew module heatshield following its return from the Artemis I flight, and previously participated in the NESC investigation of cracking in the original Orion heatshield. Having worked on the early development of the Orion heatshield, Dr. Gage brought that history and insight to the assessment. He also studied historical reports to identify early efforts to mitigate the type of material loss that was observed on Artemis I. He has also engaged with the Orion team on the definition and interpretation of tests and analyses, with emphasis on eliminating possible failure propagation pathways from future flights. "I think the NESC attracts those looking for deep understanding of causes and wanting to improve the product."

ARMSTRONG FLIGHT RESEARCH CENTER

25 AFRC Employees Supported NESC Work in FY24

The Armstrong Flight Research Center (AFRC) supported several high-profile flight research activities this year with NESC support. The X-57 all-electric aircraft project concluded after 10 years of research and development, which included a key analysis of the electric motor system by the NESC. The lessons for development of electric propulsion equipment, aircraft integration, and system design have been significant contributions to the advanced air mobility industry. The X-59 low-boom flight demonstrator is preparing for combined systems ground testing and first flight of the experimental aircraft. The NASA team worked with the NESC to evaluate critical sensors and improve the safety assurance of the aircraft instrumentation system. Meanwhile, scientists and engineers are using NASA/NESC-developed tools to analyze pilot breathing life-support flight data collected at Edwards Air Force Base this year.

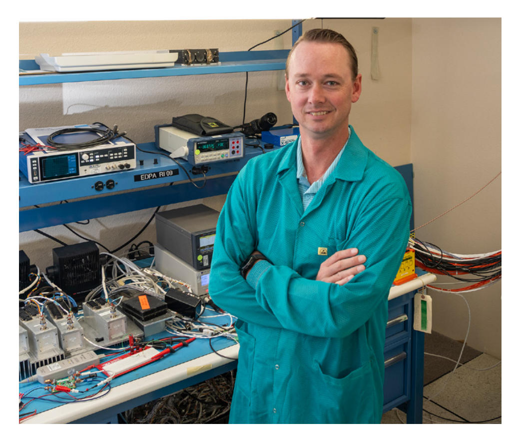
Sean Clarke
NESC Chief Engineer

Keerti Bhamidipati

Aerospace Engineer Mr. Keerti Bhamidipati (pictured right), who works in Structural Dynamics at AFRC, assisted the NESC in its support work for the Agency's all-electric experimental aircraft, X-57. "I shadowed a Technical Fellow, who was looking into the mechanical fitment of the motors. I was involved in analyzing motor vibration data to understand and characterize the vibration environment," he said. "We also used the motor vibration data to inform test specifications for the cruise motor controllers." Mr. Bhamidipati later presented his research at the Structures, Loads and Dynamics, Mechanical Systems, and Materials Early Career Forum, where he received real-time comments on his work. "I got great feedback directly from technical discipline team members on the results of my analysis. Having access to that level of technical expertise was awesome. It was great to interact and learn from the NESC's exceptional engineers."

Dr. Trong Bui

"At AFRC, I get to work on everything from engineering analyses on the computers to instrumentation in the lab to going out and kicking the tires on the airplanes," said Aerospace Engineer Dr. Trong Bui. He brings his expertise to the array of cutting-edge aircraft and aerospace technologies being researched, demonstrated, and tested at AFRC whether as an engineer and researcher, a principal investigator, or as a member of independent review boards. His work also supports the Center's airworthiness and flight-safety review process. "I found my life's calling in providing the data that management needs to make those decisions for our one-of-a-kind airplanes and irreplaceable air crews. I take great satisfaction in that work." As a new addition to the Aerosciences TDT, he is learning about issues the Agency is facing in his discipline. "I am pleased to bring the AFRC perspective to the TDT."



Matthew Versteeg

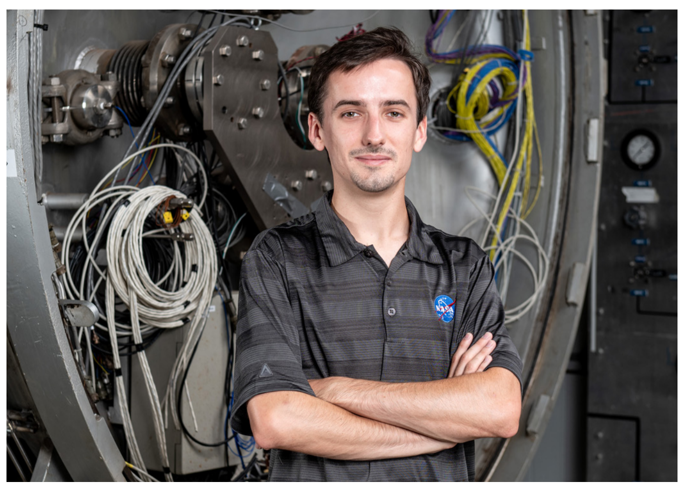
As an engineer in AFRC's Flight Instrumentation and Systems Integration Branch, Mr. Matthew Versteeg works in instrumentation system design, development, and test, as well as electrical integration for flight-test research experiments and avionics. The NESC requested his help to characterize the excitation protection on data encoders used to measure strain inside fuel tanks on NASA's X-59 airplane, designed to reduce the sound of a sonic boom. "We also tested several supplemental protection solutions that will hopefully lead to an intrinsically safe circuit on the aircraft," he said. Before his NASA tenure, Mr. Versteeg supported critical power systems operations and maintenance for IBM data centers and worked as an F-15 crew chief and electrician. "The work was similar to what I've done before, but I learned a lot. It was great getting mentorship from very experienced and knowledgeable engineers that I normally wouldn't get to interact with."

GLENN RESEARCH CENTER

73 GRC Employees Supported NESC Work in FY24

The Glenn Research Center (GRC) provided a broad spectrum of technical expertise to 30 NESC technical assessments/activities and 19 NESC TDTs. These activities supported all NASA Mission Directorates and several cross-cutting discipline efforts. Significant GRC contributions this year were in support of understanding the Power and Propulsion Element's Reaction Control Thrusters and the mechanical behavior of the aluminum alloy that makes up the Russian PrK module on the ISS. 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 GRC.

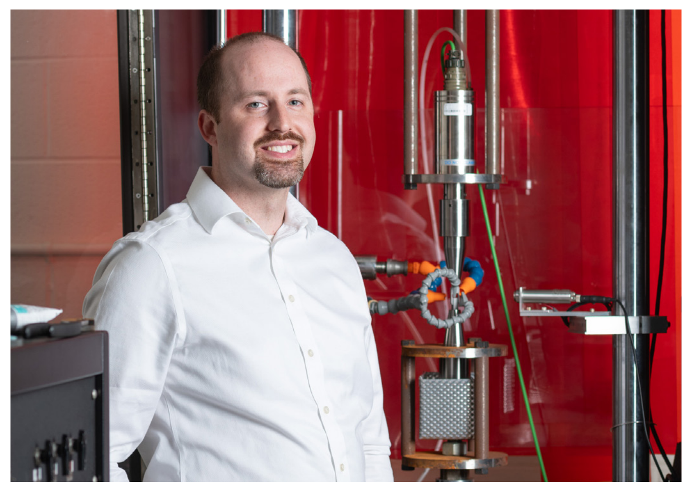
Robert S. Jankovsky
NESC Chief Engineer



Michael Cooper

The Lead Analyst for GRC's Chemical and Thermal Propulsion Systems branch, Mr. Michael Cooper, is supporting NESC test operations on reaction control system thrusters for Gateway's Power & Propulsion Element. "These thrusters are small with few moving parts, but the heat and mass transfers involved are very complex," he said. The test campaign is putting the thrusters through a rigorous profile to simulate the lifetime they will experience over decades in space. Mr. Cooper is analyzing test data gathered on chamber pressure, temperature, flow rates, and more to develop models on thruster performance. He also built the tool that read in that data from the test stand instrumentation.

"As an analyst, my work is often theoretical, imagining some scenario and trying to predict what will happen. But for this work, I was lucky enough to travel out to the test cell and support test operations for one of the thrusters. Being close to the hardware is important to me, so it was special to see some smoke and flame, and as an early career engineer in this field, to work alongside Rob Jankovsky and Kevin Dickens. They have done this work much longer than I have. Seeing what concerns them tells me what is important and what I need to be looking for."



Andrew Ring

When he was a mechanical engineering undergraduate, Mr. Andrew Ring interned at NASA doing finite element analysis, thinking that would be his eventual career. Instead, he ended up in GRC's Mechanical Test Labs as the lab manager, were he fell in love with the world of testing. "Being hands on and supporting analysts by tying their models to real-world test data is what I really enjoy," he said. Mr. Ring performs stress and fatigue testing on all manner of materials in various environments and research on jet engine materials, looking for ways to increase the performance and safety of turbine blades and disks.

Several NESC assessments have benefited from his expertise, most recently in understanding crack initiation and propagation in the aluminum-magnesium alloys that make up the modules of the ISS. He has also used image processing techniques to quantify the variables in parachute energy modulator production and performance and investigate flaws in the composite weave of overwrapped pressure vessels. "For the ISS assessment, I learned a lot about the unique properties of this aluminum alloy and how it responds to the environment. And while this is in line with my normal work, the NESC assessments have let me work with some very smart metallurgists and new materials I've never worked with before."

GODDARD SPACE FLIGHT CENTER

96 GSFC Employees Supported NESC Work in FY24

The Goddard Space Flight Center (GSFC) supported a wide range of NESC work in FY24, with 96 Goddard civil servants and dozens of contractors supporting 58 NESC assessments, support activities, and 18 technical discipline teams. GSFC supported key activities including the NASA Electronics Parts and Packaging Industry Leading Parts Manufacturer Pathfinder; 20K Cryocooler Anomaly; Balloon Program Quality Assurance; Mars Sample Return Orbiting Sample Model Review; Flight Projects Mission Critical Telemetry/Commanding Availability; Copper Wire Bond Evaluation; and the DAVINCI Mission. In addition, the NASA Technical Fellows for Systems Engineering and Mechanical Systems and the NESC Integration Office liaison for the Science, Space Technology, and Aeronautics Research Mission Directorates reside at GSFC.

Carmel A. Conaty
NESC Chief Engineer

Susana Douglas

In her Agency-wide role as Electronics Parts Manager and as the NASA Electronic Parts and Packaging Deputy Program Manager, Ms. Susana Douglas is well versed in electrical, electronic, electromechanical parts usage in NASA missions. That is why the NESC tapped her to be the technical lead for its Industry Leading Parts Manufacturer (ILPM) Pathfinder assessment, which follows the NESC's years-long effort to develop commercial-off-the-shelf (COTS) parts guidance for NASA missions. In this pathfinder activity, Ms. Douglas led the ILPM vetting process with a commercial provider's chip resistors to understand their reliability. Manufacturers who go through this process become ILPMs whose parts can be used in NASA designs without the extensive testing process normally required for COTS parts.

"As more of our commercial developers use these parts, NASA needs to be more educated and comfortable with using them," Douglas said. "By working with manufacturers to find sources of supplies that meet our criteria, we can evaluate and develop test plans for any gaps between what the product does and what our needs are. We'll house this information in an Agency-wide database available to parts engineers and designers. I think the ILPM concept is terrific, and we need to find a way to ingrain it into our parts assurance standards at the Agency."

Wendy Morgenstern

Ms. Wendy Morgenstern has assisted the NESC both on multiple assessment teams and as the deputy for the Systems Engineering TDT, bringing a wealth of expertise from her nearly 35 years at GSFC. As a Mission Systems Engineer, she has led the development, launch, and commissioning of multiple missions like the Solar Dynamics Observatory. "I make the mission work across all elements—ground, flight, science instruments, test, verification—from cradle to grave," she said.

Recently, she brought a fresh perspective to the NESC's cryocooler support assessment, methodically pouring through 200+ documents for an in-depth look at the entire program, going back to the beginning of the cryocooler development. "Even the people doing the day-to-day work, who very much wanted to take this kind of look themselves, don't get to slow down to do it. That's one way we can help." She said the NESC "really looks across the Agency in so much breadth and depth," much like her own discipline. "I always say high-level systems engineering is like constantly studying for a master's thesis on something you probably didn't know much about before you came to work that morning. You never know what's going to wind up on your desk, but you have to figure out the problem and make a decision quickly. I love doing that."

JET PROPULSION LABORATORY

102 JPL Employees Supported NESC Work in FY24

Kimberly A. Simpson
NESC Chief Engineer

The Jet Propulsion Laboratory (JPL) provided technical leadership and engineering expertise to 25 new or ongoing NESC assessments and 19 TDTs in 2024. More than 100 JPL employees made significant contributions to NESC assessments this year including the development of simulation check cases for lunar environments, Orion crew module uprighting system modeling, support of the Boeing Starliner, review of the NASA-Indian Space Research Organisation Synthetic Aperture Radar antenna reflector thermal model, contributions to the NASA Valve Standard development, and thermal testing in support of lunar glove analysis. More than 65 JPL employees served on TDTs working with NASA Technical Fellows on advancement of Agency engineering initiatives. JPL provides leadership for the COPV Working Group and the TDT deputies for Space Environments, Electrical Power, and Mechanical Systems reside at JPL.

Dr. Richard Blank

Dr. Richard Blank's support to the NESC enabled a focused view into the CCP. At JPL, his focus has been supporting tiger teams to resolve flight project anomalies and failures, an expertise the NESC found invaluable for its failure investigation of pyrotechnic smart initiators used by CCP partners and evaluation of nondestructive screening techniques to examine fully configured flight hardware.

"I was intrigued by the complexity of the CCP and working in an environment where industry is given a much stronger leadership role. And I was impressed by how well CCP and NASA navigated this new environment and seeing NASA working in this inclusive manner." He appreciated the diverse technical expertise within the NESC and how well the team communicated with each other and the stakeholder. "It was all very inclusive. I talked with chief engineers from NASA and CCP, and they listened. Our findings were heard and used to make a decision," he said. "We are all human beings trying to do good things, but we may take very different approaches to doing so. Sometimes we disagree, and that's okay, as long as we do it respectfully. I thought it was a very good and positive experience."

Gregory Carr

Mr. Gregory Carr has worked at JPL for 33 years and is the Power Section Chief Engineer where he works on the power system architecture for new missions. "I follow the development through flight delivery and lead peer reviews and tiger teams when there are issues," said Mr. Carr, who assisted the NESC in its evaluation of radiation hardness for the metal oxide semiconductor field effect transistors (MOSFET) used on the Europa Clipper, which launched in October 2024 to study Jupiter's moon for signs of life. "Europa is a high radiation environment," said Mr. Carr, "so it was critical that we do a quick assessment of the MOSFETs prior to launch." He also assisted the NESC on the power control for the Europa Clipper and has supported reviews for the Dragonfly rotorcraft that will explore Saturn's moon Titan.

Mr. Carr serves as a discipline deputy for the NESC's Electrical Power TDT and is involved in many power electronics issues and analyses. "I like looking deeper into the designs to figure out what the issue might be. I also enjoy working with other subject matter experts in the field, learning from their experiences, and doing the analysis that helps them to solve issues they discover and come to a consensus on root cause."

JOHNSON SPACE CENTER

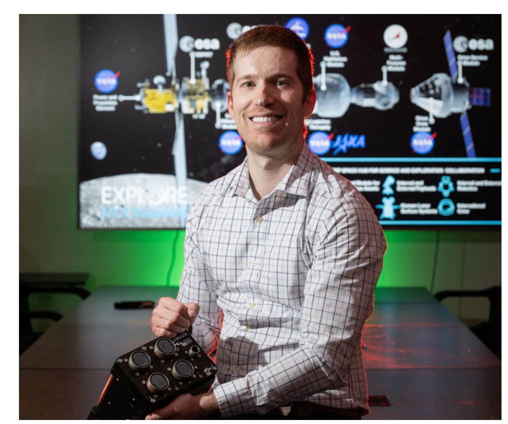
150 JSC Employees Supported NESC Work in FY24

Joel W. Sills
NESC Chief Engineer

In 2024, the Johnson Space Center (JSC) and White Sands Test Facility (WSTF) engineering, test, and operations personnel provided engineering expertise to 35 NESC activities while 150 engineers supported 17 NESC TDTs. The NESC and the JSC Engineering Directorate investigated the Orion heatshield char loss and release and retention bolt erosion in preparations for Artemis II. Structural, materials, and NDE engineering teams continue to investigate root cause for the ISS Russian segment PrK cracks to inform programmatic risk discussions and future operations. Software personnel investigated human-rated vehicle software, identifying mitigations to erroneous outputs during entry. Resident Technical Fellows continue to strengthen technical community connections through joint sponsorship and participation in NASA, other governmental, and academia activities.

Susana Harper

Ms. Susana Harper has been actively involved in two assessments this year, both of which involved developing new flammability test methods. Working at WSTF, Ms. Harper's 20 years of flammability testing experience was crucial in characterizing how effective FM-200 fire suppressant would be at extinguishing crew module zero-gravity fires and, more recently, in determining how material flammability extinguishment limits will change in the lunar gravity environment. "Understanding that will tie back to how we select the materials we'll use on the Moon," she said. NESC support work is an exciting part of the work she performs as the Flight Acceptance Standard Testing Manager. "The NESC projects can be cutting edge. They push you to develop something new, and test development and test method planning are my favorite parts of my job. We're answering new questions that have not been answered before."



Dr. Andrew Loveless

Dr. Andrew Loveless is the Networking Technical Discipline Lead for the Command and Data Handling Branch. Currently, he is planning tasks to mature and test the network architecture for Gateway's power and propulsion and habitation modules and researching ways to improve the safety and performance of networked avionics systems for crewed deep-space exploration. Using his expertise in networking and failure tolerance, Dr. Loveless helped lead the development of an NESC paper, "Best Practices for Designing Failure-Tolerant Avionics for Crewed-Space Systems," which focuses on the additional rigor required to show an avionics architecture is sufficiently safe for human spaceflight. "The project allowed me to positively influence many different NASA programs at once," he said. "Future managers can learn to avoid a lot of the challenges experienced in past NASA programs, and we can influence human spaceflight work going on outside of NASA as well."

Dr. Adam Sidor

Dr. Adam Sidor is a Thermal Protection Engineer for JSC's Thermal Design Branch. As a thermal protection systems (TPS) subsystem manager for CCP, his work ensures provider's systems are safe for crewed flight. He is also lending his expertise to the NESC's assessment of the Artemis I Orion heatshield. "I've done a variety of experimental tests to get a good understanding of the TPS materials and their application," he said. His interest in TPS goes back to graduate school, where his thesis was on TPS manufacturing, as well as an early career initiative project to develop TPS 3D printing. He has particularly enjoyed the opportunity to examine a heatshield subjected to the ultimate test flight. "It's been a great experience. I personally get to contribute to something that's very significant to NASA's mission and provide insight on how we move forward with Artemis II and beyond. It's exciting to be a part of that."

KENNEDY SPACE CENTER

53 KSC Employees Supported NESC Work in FY24

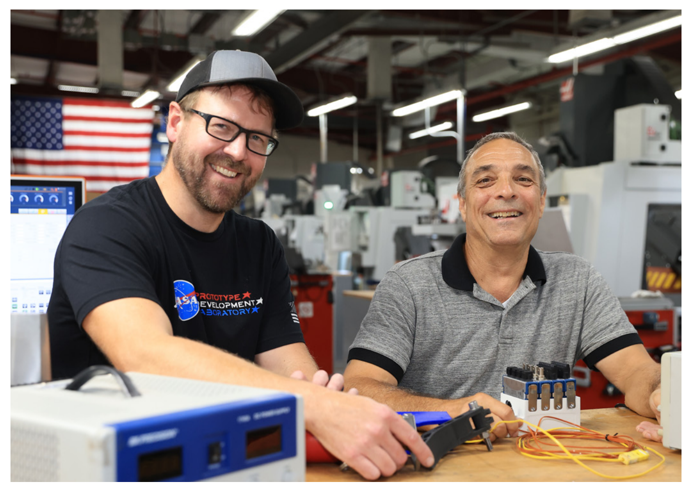
The Kennedy Space Center (KSC) personnel provided technical expertise to 44 NESC activities and TDTs in 2024. They engaged in numerous NESC assessments including Agency-wide testing for cleaning and thermal solvent replacement; JSC Mission Control backup electrical power assessment; and Exploration Systems independent modeling and simulation. Likewise, the NESC supported KSC programs with numerous activities, such as providing CCP with portable fire extinguisher microgravity compatibility testing; mobile launcher launch-induced damage analysis and modeling; and support for CCP Dragon GPS anomaly resolution. The NESC also invested in KSC's laboratories to perform spacesuit water membrane evaporator testing, CCP portable fire extinguisher testing, and Agency solvent compatibility testing. The NASA Technical Fellow for Electrical Power resides at KSC and relies on KSC expertise in many of his activities.

Stephen A. Minute
NESC Chief Engineer

David Chesnutt

Working in KSC's Engineering Analysis Branch, Mr. David Chesnutt is providing structural analysis of the Center's ground support equipment for the Artemis Program. "We want to understand the launch-induced environment of SLS and its effect on ground hardware like the mobile launcher and umbilicals," he said. He is using thermal and pressure data from simulated plumes correlated with Artemis I measurements to help predict the intensity of the chaotic launch environment. "It's been a daunting endeavor, but I love large, complex datasets and combing through the details."

Mr. Chesnutt has a unique history with the NESC, both as someone who has had his work peer-reviewed by the NESC and as a deputy for the Structures TDT. He works to keep the discipline healthy, staying on top of industry manufacturing methods and analysis techniques, and managing the TDT's diverse skill set. And since his days as an early career engineer, he has attended the annual NESC-sponsored SLAMS workshop and is now one of the mentors for the event. "It's creating this foundation for the next generation of engineers who may one day be a TDT member or deputy. Or maybe one day a NASA Technical Fellow will come from the SLAMS community. It's a very powerful event that I'm really proud to be a part of."



Timothy Provin & Justin Youney

Mr. Timothy Provin and Mr. Justin Youney, engineers from KSC's Prototype Development Laboratory, recently helped the NESC collect data on how a terrestrial portable fire extinguisher would perform in microgravity. Mr. Provin, Mechanical Design Engineer, designed and built a mock-up of a crew module's floor and spaces beneath it. The work involved everything from cutting plywood to wiring and 3D printing of parts.

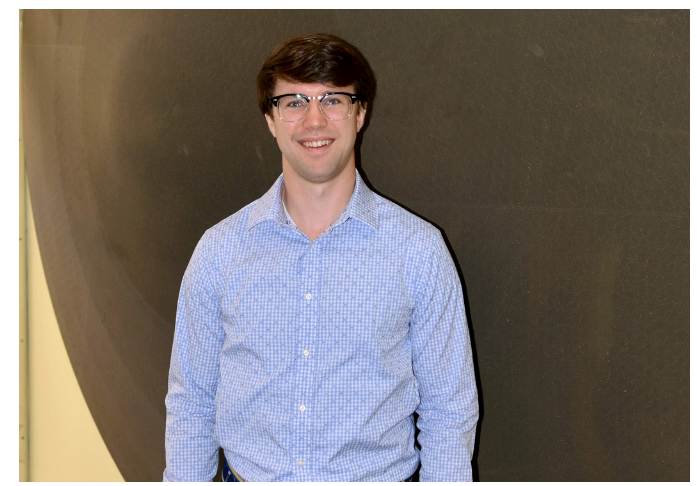
Mr. Youney, Lead Electrical Controls Engineer, evaluated oxygen sensors, and chose one that was temperature compensated to account for temperature variations in the crew module's subfloor where the PFEs would be used. "I then created a data acquisition system that would report time-stamped data as the PFEs were fired," said Youney, who enjoyed the fast-paced project. "Working with the NESC allows for fast prototyping and quick creative turnaround. This lets scientists evaluate different scenarios rapidly and make educated decisions." For Mr. Provin, it was a unique opportunity to work with people from different centers. "We had to quickly determine the sufficiency of these PFEs in microgravity, so we did a lot of brainstorming to figure out the best way to get the results and ensure we could trust those results. It was the kind of project that throws you outside of your normal box and lets you see what you can do."

LANGLEY RESEARCH CENTER

206 LaRC Employees Supported NESC Work in FY24

During FY24, the Langley Research Center (LaRC) provided technical and specialized facility support for more than 60 NESC assessments, engaging 206 technical experts to resolve challenges being worked across the Agency. LaRC experts engaged in activities such as analyzing the GPS system design for CCP; dynamic high-speed extension testing of energy modulators used in parachute extraction systems; and providing an independent fracture mechanics review of existing cracks and potential crack propagation in support of the ISS. Multiple LaRC facilities such as the Landing and Impact Research Facility, the Materials Research laboratory, the Nondestructive Evaluation laboratory and the EMI/EMC laboratory were used in support of NESC activities. These efforts allowed the NESC to accomplish its mission to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects.

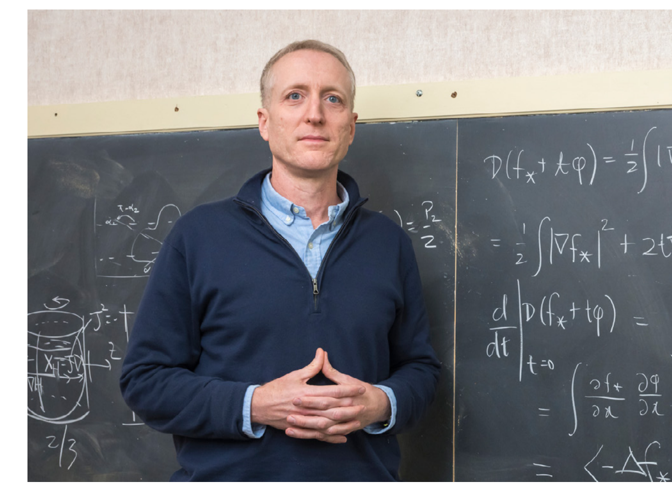
K. Elliott Cramer
NESC Chief Engineer



Jacob Fleck

Working in LaRC's Atmospheric Flight and Entry Systems Branch, Flight Mechanics Engineer Mr. Jacob Fleck works on generating high-fidelity flight simulations and trajectory analyses for entry vehicles. But his recent work for the NESC had him going in a different direction, doing 6-degree-of-freedom ascent simulation and modeling for SLS. Mr. Fleck joined an ongoing NESC assessment to develop independent SLS flight simulations to mitigate integration risks with the elements that impact design and performance. "There's a lot of interest in the vehicle's flight performance during separation events, such as booster or panel separations, because these maneuvers are considered higher risk. We want to see that our simulations are within design requirements and there's no vehicle recontact after separation."

For the SLS analysis, he uses the NASA-developed Program to Optimize Simulated Trajectories software. "SLS is more complicated than many of the entry capsules we typically work on, and it pushes us to use every single aspect of this software." The work uses both his aerospace engineering and mathematics skills and taps into his love of computational analysis. "I find the Artemis Program exciting, and doing trajectory simulations is very much what I was hoping to do after school."



Dr. Peter Spaeth

As a senior physicist in LaRC's Nondestructive Evaluation Sciences Branch, Dr. Peter Spaeth develops algorithms to interpret the results of inspections performed on new aerospace materials and hardware. Using a combination of data science, physics-based modeling, and high-performance computing, he deciphers data from inspection techniques like X-ray computed tomography (CT), ultrasound, infrared thermography, and others used to peer inside a specimen without damaging it.

Recently, he was asked to develop an algorithm to analyze data from the Orion heatshield following its return from the Artemis I mission. Since the heatshield was too large for the CT system, it was examined using a relatively new backscatter X-ray technique that can provide three-dimensional volumetric information. Dr. Spaeth created an algorithm to look at more than 100,000 images and provide the NESC a quantitative mapping of the heatshield. "The idea was to understand the effects of reentry on the heat-absorbing material and estimate the remaining thicknesses of the different material layers," he said. "It was really gratifying to work with a new inspection system. I believe we'll have many more opportunities to use this technique as new heatshields come back. There's just so much we can do, and I think the best is yet to come."

MARSHALL SPACE FLIGHT CENTER

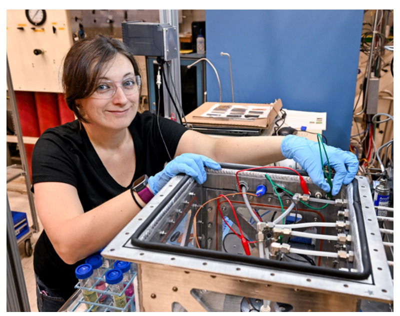
115 MSFC Employees Supported NESC Work in FY24

The Marshall Space Flight Center (MSFC) continues to provide exceptional engineer, scientist, and technician subject matter expert support to 44 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 (ECLS), and Flight Mechanics, and the TDT Deputies for Propulsion, Nuclear Power and Propulsion, Materials, Space Environments, Loads & Dynamics, Nondestructive Evaluation, ECLS, Structures, Sensors & Instrumentation, and Software are resident at MSFC.

Steven J. Gentz
NESC Chief Engineer

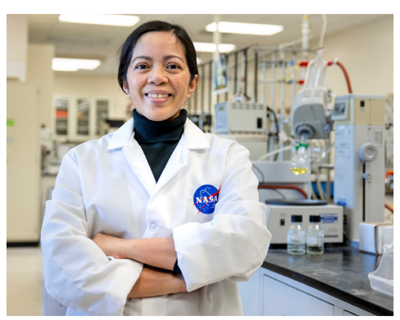
Dr. Matt Hawkins

As the Human Landing System (HLS) deputy discipline lead for guidance, navigation, and control, Dr. Matt Hawkins was the ideal candidate to co-lead an NESC assessment to develop benchmark check-cases for simulations to compare with HLS models. The work will also provide a public library of check-cases to help validate simulations. "It's a way to compare different simulations, run tests, and ensure you are getting the same results," he said. "While my previous work has been more Earth-based, now we're heading to the Moon, and we need a variety of scenarios to ensure we can test anything that might come up." See NESC Technical Bulletin 24-04.



Dr. Kaitlin Oliver-Butler

Dr. Kaitlin Oliver-Butler's work in the ECLSS Development System Branch focuses on air revitalization systems that scrub carbon dioxide from spacecraft cabin atmospheres and reclaim oxygen for the crew. This expertise was valuable to the NESC's investigation of ammonia cartridges used in emergency masks at ISS. She studied mask requirements and materials to not only aid in the investigation but also inform mask design for the Orion crew vehicle. "I enjoyed working with team members from JSC and learning about their processes, as well as the chance to do something, that while tangential to what I normally do, was still new and different."



Dr. Lorlyn Reidy

Chemist Dr. Lorlyn Reidy helped assess potential replacements for organic solvents NASA uses in precision cleaning of hardware and heat transfer that are facing obsolescence. "We're evaluating the thermal and physical properties of the candidate fluids like density, kinematic viscosity, vapor pressure, and heat capacity," she said. While her typical work involves investigating ionic liquids for space applications and developing technology for oxygen and metal recovery from lunar regolith, the NESC work allowed a chance for intra-Agency collaboration. "It's motivating and inspiring to work alongside experts from several NASA centers to find solutions to technical challenges. Everybody contributes to the success of the project."

Dr. William Stein

Mission Analyst Dr. William Stein served as co-lead on the NESC's disposal study of the SLS's upper stage. His analysis confirmed its disposal was unintentionally resulting in known 3-body periodic orbits that could result in an early return to Earth depending on the launch window. Dr. Stein helped describe the orbital geometries that could be avoided in future launches to minimize the early return risk. "This work had direct applications and impact on how SLS could possibly fly. This work included both the theoretical work and the practical application, which made it a fun project."

STENNIS SPACE CENTER

21 SSC Employees Supported NESC Work in FY24

The Stennis Space Center (SSC) provided expert technical support to the NESC during 2024, including subject matter expertise in several of the NESC's TDTs. SSC members in the Thermal Control & Protection, Systems Engineering, and Software TDTs were key participants in planning and strategy sessions for yearly TDT face-to-face meetings. Other SSC engineers have become valuable contributing members of the Propulsion, Cryogenics, Human Factors, Aerosciences, Loads & Dynamics, Structures, and Mechanical Systems TDTs. SSC continued to offer unique propulsion testing facilities for proposed NESC assessments.

Michael D. Smiles
NESC Chief Engineer

Rae Lyn Anderson

Ms. Rae Lyn Anderson is the SSC software assurance subject matter expert, where she has worked for NASA since 2011. As the technical lead for the software assurance team, she supports the SLS Exploration Upper Stage green run testing and NASA Data Acquisition System as well as the NASA Autonomous Satellite Technology for Resilient Applications (ASTRA). She ensures SSC software projects are compliant with NASA software procedures and standards throughout the software development life cycle.

During her tenure at SSC, Ms. Anderson has also supported the NESC Software TDT, where she meets regularly with employees across the Agency to review changes to governing software policy requirements, supports Agency surveys and data-gathering calls, and networks with the NASA software discipline community. "All NASA centers come together in this working group," she said, which has given her a large list of contacts for those times she needs assistance or ideas for implementing new software requirements. "When issues arise or a process isn't working, that's when we need to develop an alternate way to meet the intent of the requirements that helps the project to become more efficient, and I like the challenge of figuring out a solution."

Glen Guzik

At SSC for 10 years, Mr. Glen Guzik supports propulsion testing of the Artemis Core Stage RS-25 engines at the SSC A-1 test stand. As part of the Engineering and Test Directorate's Mechanical Engineering branch, he oversees the design and analysis of facility systems that provide fluid commodities to the engine during test. "I prepare or approve piping and instrumentation diagrams and mechanical sketches and interact with the test team to ensure designs will meet the requirements of the system," he said.

Recently, as part of the planning team for the annual NESC Systems Engineering Workshop, he served as both SSC and virtual experience lead where he ensured remote attendees had the same experience and opportunity to network as those who attended in person. "It's been a great opportunity to promote knowledge sharing across the Agency in the systems engineering discipline and interesting to see the projects other centers are involved with and how they overcome challenges and achieve their missions. It's also nice to take a break from what is largely SSC's singular focus of propulsion testing and gain some exposure to Agency-level programs and goals."

NESC KNOWLEDGE SHARING

Workshops, Mentoring, and Knowledge Products

In its 21 years, the NESC has completed more than 1,300 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.

In the following pages, the NESC highlights just a few of its efforts to share the knowledge learned in the resolution of NASA's toughest technical challenges.

FY24 NESC-SPONSORED 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.

- **Aerospace Battery Workshop**
- **Agile Community of Practice Technical Interchange Meeting**
- **Applied Space Environments Conference (ASEC)**
- **Program to Optimize Simulated Trajectories II (POST2) Workshop**
- **Software Engineering 101 Roadshow**
- **Spacecraft Anomalies and Failures (SCAF) Workshop**
- **Structures, Loads & Dynamics, Materials, and Mechanical Systems (SLAMS) Early Career Forum**
- **Systems Engineering Workshop**
- **Thermal and Fluids Analysis Workshop (TFAWS)**

View upcoming NESC events at **NASA.GOV/NESC**

Attendees gathered at the 13th annual NASA SLAMS Early Career Forum in front of a mockup of an Apollo Command/Service Module.

Structures, Loads & Dynamics, Materials, and Mechanical Systems Early Career Forum

July 2024

The 13th annual NASA SLAMS Early Career Forum was held in July at WSTF. The forum gave early-career engineers across the Agency the opportunity to showcase their work and develop relationships with peers and mentors with the aim of advancing the SLAMS fields for the future. Technical briefings spanned multiple topics such as lunar tethers, in-space manufacturing, thermal vibration, instrumenting parachute canopies, and testing and modeling of elastomers at cryogenic temperatures. The event included mentoring sessions with senior engineers, small group discussions, tours, and social events.

Spacecraft Anomalies and Failures (SCAF) Workshop

March 2024

The annual SCAF Workshop, organized by the NESC Space Environments TDT and the National Reconnaissance Office, presented topics including radiation impacts on Chandra X-ray Observatory science operations, the ICON failure and NOAA-17 breakup, spacecraft charging of GOES-R, ISS optical monitoring and anomaly resolution, software anomalies, and radiation anomalies in the GSFC anomaly database and using the SPARK tool to correlate anomalies in the database with space weather events. The workshop focused on improvements in space system anomaly and failure attribution and refining and documenting best practices for root cause determination. It brought together civil, industry, academia, and military personnel who would not normally have a chance to interact.

Topics addressed at the SCAF Workshop included radiation impacts on Chandra X-ray Observatory science operations and ISS optical monitoring and anomaly resolution.

Aerospace Battery Workshop

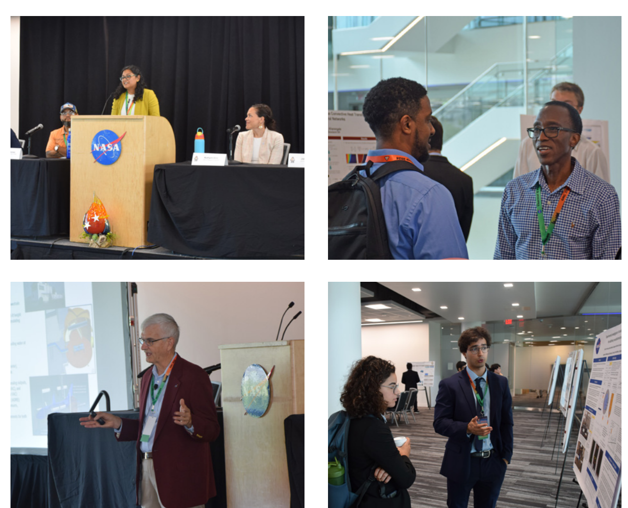
November 2024

The NASA Aerospace Battery Workshop is an annual event hosted by MSFC and is sponsored by the NESC in Huntsville, AL. The workshop is typically attended by scientists and engineers from various agencies in the U.S. Government, aerospace contractors, and battery manufacturers, as well as international participation from a number of countries around the world. Subjects covered include research and development work on state-of-the-art aerospace battery technologies, flight and ground test data, on-orbit operation and problem resolution efforts, and many other related issues.

Thermal and Fluids Analysis Workshop (TFAWS)

August 2024

NESC continued its support of the TFAWS through sponsorship by the Thermal Control & Protection, Aerosciences, Cryogenics, and Environmental Control & Life Support TDTs. TFAWS 2024 was held in Cleveland, Ohio, and was presented by GRC in collaboration with the cross-Agency TFAWS Steering Committee. A total 320 personnel attended the workshop and included NASA, industry, academic, and international participants. Activities included presentations, theory-based short courses, vendor booths and demos, hands-on analysis tool training, panel discussions, guest speakers, a speed-mentoring session for students and early career engineers, a student poster session, and tours of Armstrong Test Facility and GRC facilities.



Presenters and attendees at TFAWS, August 2024.

One-on-One Mentoring Program Builds Cross-Center Relationships

At the annual Systems Engineering Workshop in May 2020, Ms. Vickie Wood and Mr. Justin Fada, both on the workshop's planning committee, had an inspiring idea. In reading the workshop's exit surveys, one event stood out as a big hit among attendees: a breakout session where participants, at various career stages and from different NASA centers, were randomly assigned to small groups.

"At those breakout sessions, engineers had discussions and learned how other centers implemented their system engineering practices and procedures," said Mr. Fada. Significant mentoring happened in those sessions, he said. "It seemed like something we needed to continue in order to keep that mentoring aspect alive."

Mr. Fada and Ms. Wood had put a lot of work into developing those sessions to make them meaningful for participants, especially since the pandemic required a virtual workshop that year. "We found subject matter experts to help us facilitate conversations in those virtual breakout rooms and that's where this brainchild really developed," added Ms. Wood. "We saw the value of that knowledge getting to the younger workforce."

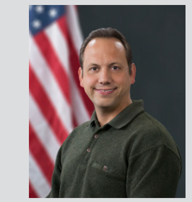
What resulted was a one-on-one cross-center mentoring program that pairs mentors with mentees, who have hour-long conversations each month for a year. "While exchanging ideas, experiences, best practices, career advice and more, they would also be building a personal relationship with someone from another center," Mr. Fada said of the concept.

The pilot program brought together 10 pairs of mentors and mentees, and feedback was positive. "Ninety percent of people were giving us five-star reviews," said Mr. Fada. This year it has grown to 20 pairs. Ms. Wood and Mr. Fada attribute the success to the upfront work they do to pair mentors with mentees, using biographies of each to ensure a good match—not only in career paths and goals but in personal interests as well.

"We had been involved in the workshop planning committee for so long," said Ms. Wood, "that we'd made some really good contacts and had a nice, solid set of mentors that helped us kick off our first year."

"We have an Agency workforce eager to learn from each other, learn from each other's history and culture and projects, and the bread and butter of how each center implements systems engineering practices. So this one-on-one mentoring program is how we addressed that need," Mr. Fada said. "We're really enjoying the program and getting a lot from it, so I think we're going try to continue this for as long as we can."

"The program gave me an avenue to both technical and non-technical discussions with a division chief at another NASA center. Not only was the mentoring experience useful in gaining additional insight into the decisions driving roles and responsibilities within the Artemis Program, but it also provided a means to understand the evolution of the NASA systems engineering process from an expert. Being a listed contributor in the NASA Systems Engineering Handbook, my mentor provided a first-hand account of how lessons learned have driven systems engineering process changes to positively impact crew safety and mission success as we take on increasingly complex Artemis missions."



Darren Baird, JSC

"Although I was identified as the mentor, the exchange of information was more along the lines of mentee to mentee. I was able to share my career paths and experiences being at one center and likewise with my counterpart at another center. Over the year-long program, I believe each of us walked away with more knowledge and experience that we can apply in our daily work life, and we also shared happenings in our personal life that I can say I have another friend."

Neil Rainwater, MSFC

"I've only worked one project while at NASA, so having a mentor from a completely different center helped me understand what I had learned about systems engineering (terms, expectations, etc.) was specific to my project and what was NASA standard process. My mentor helped me through some difficult interactions at work, explained the purpose and importance of many types of reviews, and was generally there for me when I needed guidance. I still keep in touch with my mentor and she will continue to be not only a great resource for me as a systems engineer, but also an amazing friend."

Christy Schmid, GRC

"I have supported the SE mentoring program as a mentor for each of the first three years across four centers. As with any mentor-mentee pairing, the mentor has the opportunity to gain from the experience as well. And the value of having cross-Agency pairings cannot be over stated. So much in common, yet fascinating to discover the differences between the centers. I found each of my pairings to be excellent, and we never struggled to find things to discuss. Interestingly, in each of the pairings we rarely discussed technical topics but focused more on navigating the NASA processes and working relationships. I always enjoy mentoring, and this mentor program is exceptionally well executed from the initial vision to implementation."

Timothy Schuler, GRC

Fueling Innovation: How Agile Practices are Transforming NASA


Participants of the NASA Agile TIM.

NASA has formally instituted an Agile Community of Practice (CoP) with representation from all centers across the Agency. It is sponsored by the NESC Systems Engineering TDT with involvement of other disciplines. The purpose of the NASA Agile CoP is to exchange knowledge, experience, and ideas among Agile practitioners across the Agency, and help new adopters in their Agile transformations. The efforts include strategic and tactical activities and products to meet the needs of the practitioners aligned to the Agency's strategic goals.

While 2020 saw a focus on Model-Based Systems Engineering and digital tooling, the current landscape demands a broader approach. Today, industry emphasizes making systems engineering itself more agile and adaptable encompassing both technical and programmatic domains. Recognizing that cultural change is not solely driven by tools, insights from a comprehensive study of Agile teams at NASA provided a foundation for the Agile CoPs strategic plan, which included a strengths, weaknesses, opportunities, and threats (SWOT) analysis, leadership capacity to ensure impact and sustainment, and a road map with short-term and long-term objectives and strategies.

The NASA Agile CoP 2023-24 Report provides a comprehensive summary of the products and activities executed by the NASA Agile CoP over its first year. The report highlights the community's ongoing efforts to advance Agile values and principles, improve practices, and foster innovation within teams across NASA. The report delves into key initiatives, including the development of a strategic plan, executive summary, and best practice guidelines, as well as the facilitation of knowledge-sharing events such as webinars with internal and external speakers, workshops, and a technical interchange meeting. It also examines the impact of these activities on organizational agility, team performance, and overall product success through case studies, feedback from community members, and metrics. This shows the community's role in driving continuous improvement and supporting the broader adoption of Agile principles.

By fostering collaboration and expertise in Agile practices, the CoP seeks to shape a future where NASA continues to develop missions with greater agility, efficiency, and impact.

View these newly released videos at the NESC Academy website to learn more about Agile and how some organizations are applying it to NASA projects.

- *Tailoring Agile Approaches to Drive Earth Science Research and Development Projects*
- *Scaled Agile Framework and the Effects on a Cyber Security Team*
- *NASA Stennis Space Center's Agile Journey*
- *NASA Launch Services Program (LSP) Systems Engineering Collaboration with SpaceX*
- *Impact of Software Architecture on Team Agility*
- *How OpenMDAO Maximizes our Impact with Agile Practices*
- *Agile Principles from the Buy and Fly Hardware Certification Process*
- *Agile Approach on Hardware-Centric Project*
- *Agile in NASA 2040*
- *Agile Flight Software Development in NASA's Waterfall World*
- *Value-Driven Product Delivery via Agile Mindset*
- *Scaling Agile to Reach New Heights Even Among Budget Constraints*
- *Agile Implementation in the Development of the Aeronautics Research Mission Directorate Test Data Portal*

View Agile videos at:
NESCACADEMY.NASA.GOV

Join the Agile community:
(For NASA employees)
NEN.NASA.GOV/WEB/AGILE
AGILE TEAM CHANNEL

AGILE
NASA Community of Practice
Educate • Collaborate • Innovate

Guiding Values & Principles

Embrace Change	Deliver Value Early and Often	Collaborate with Stakeholders	Empower Teams	Measure and Learn
Be flexible and adaptable. Welcome change as an opportunity to improve by continuously adapting plans based on feedback.	Plan and break down work into small, manageable chunks, and deliver working products frequently to meet the needs of the customer.	Work with stakeholders to communicate regularly about your progress and plans. This will help to ensure they are aligned and contribute to your goals.	An agile team is self-organizing, self-managing, and has the authority to make data-informed decisions to achieve shared goals.	Regularly measure and reflect on progress. Learn from intelligent mistakes and successful outcomes. Make frequent process adjustments as needed.

NESC KNOWLEDGE PRODUCTS

The NESC is engaged in activities to identify, retain, and share critical knowledge in order to meet our future challenges. To disseminate that knowledge to engineers—within NASA, industry, and academia—the NESC develops 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)* 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 & 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 & Safety Center

Providing 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, downloadable course materials, and more.

The NESC Academy website now features:

- **104 new videos in FY24**
- **A more intuitive, user-friendly interface**
- **Faster, smoother navigation**
- **Customizable playlists tailored to your interests**
- **Curated Academy playlists on cutting-edge topics like lunar lighting, thermal testing and verification, space solar arrays, shock and vibration, grounding and shielding, and attitude control systems.**

Learn more about new playlist features at:
NESCACADEMY.NASA.GOV/PLAYLISTS

Most Viewed Videos by Discipline FY24

AEROSCIENCES
System ID Methods for Aero Modeling and Validation

AVIONICS
Fundamentals of Electromagnetic Compatibility, Part 1

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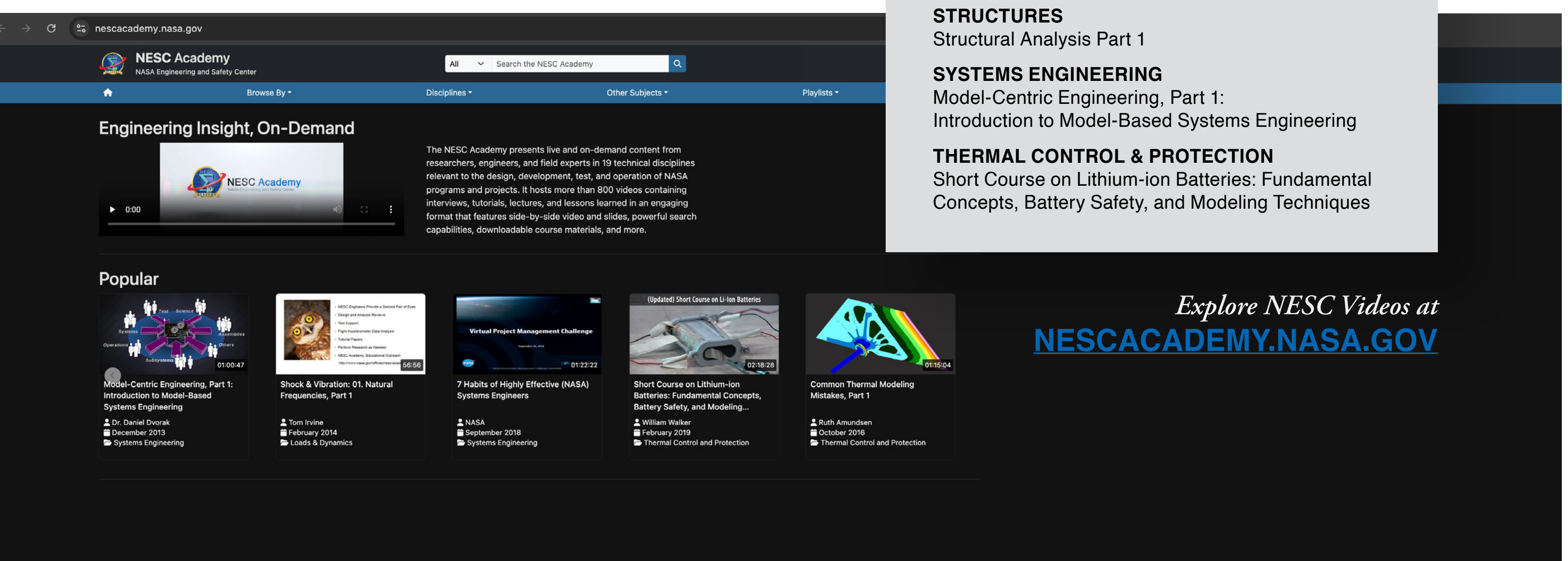

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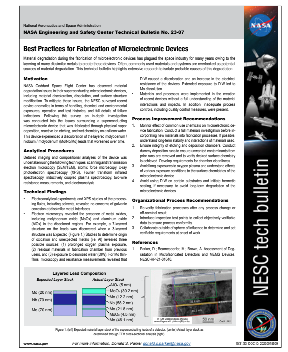
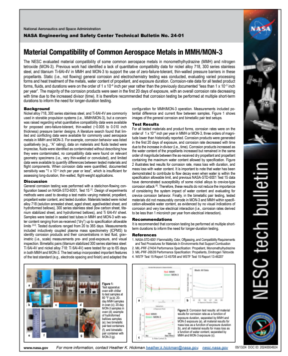


Technical Bulletin 23-07

Best Practices for Fabrication of Microelectronic Devices

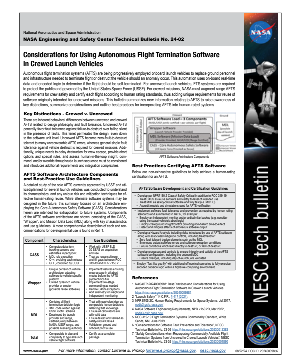
Material degradation during the fabrication of microelectronic devices has plagued the space industry for many years owing to the layering of many dissimilar metals to create these devices. Often, commonly used materials and systems are overlooked as potential sources of material degradation. This technical bulletin highlights extensive research to isolate probable causes of this degradation.



Technical Bulletin 24-01

Material Compatibility of Common Aerospace Metals in MMH/MON-3

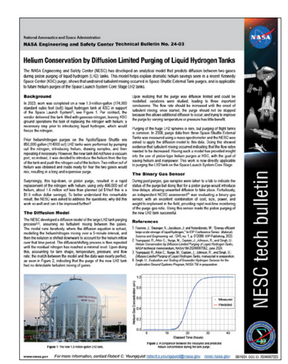
The NESC evaluated material compatibility of some common aerospace metals in monomethylhydrazine (MMH) and nitrogen tetroxide (MON-3). Previous work had identified a lack of quantitative compatibility data for nickel alloy 718, 300 series stainless steel, and titanium Ti-6Al-4V in MMH and MON-3 to support the use of zero-failure-tolerant, thin-walled pressure barriers in these propellants. Static (i.e., not flowing) general corrosion and electrochemistry testing was conducted, evaluating varied processing forms and heat treatment of the metals, water content of propellant, and exposure duration. Corrosion-rate data for all tested product forms, fluids, and durations were on the order of 1 x 10^{-6} inch per year rather than the previously documented "less than 1 x 10^{-3} inch per year." The majority of the corrosion products were seen in the first 20 days of exposure, with an overall corrosion rate decreasing with time due to the increased divisor (i.e., time). It is therefore recommended that corrosion testing be performed at multiple short-term durations to inform the need for longer-duration testing.



Technical Bulletin 24-02

Considerations for Using Autonomous Flight Termination Software in Crewed Launch Vehicles

Autonomous flight termination systems (AFTS) are being progressively employed on board launch vehicles to replace ground personnel and infrastructure needed to terminate flight or destruct the vehicle should an anomaly occur. This automation uses onboard real-time data and encoded logic to determine if the flight should be self-terminated. For uncrewed launch vehicles, FTS systems are required to protect the public and are governed by the U.S. Space Force. For crewed missions, NASA must augment range AFTS requirements for crew safety and certify each flight according to human rating standards, thus adding unique requirements for reuse of software originally intended for uncrewed missions. This bulletin summarizes new information relating to AFTS to raise awareness of key distinctions, summarize considerations, and outline best practices for incorporating AFTS into human-rated systems.



Technical Bulletin 24-03

Helium Conservation by Diffusion Limited Purging of Liquid Hydrogen Tanks

The NESC has developed an analytical model that predicts diffusion between two gases during piston purging of liquid hydrogen (LH2) tanks. This model helps explain dramatic helium savings seen in a recent KSC purge, shows that undesired turbulent mixing occurred in Space Shuttle external tank purges, and is applicable to future helium purges of the SLS Core Stage LH2 tanks.

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Statistical Analysis Using Random Forest Algorithm Provides Key Insights into Parachute Energy Modulator System

Energy modulators (EM), also known as energy absorbers, are safety-critical components that are used to control shocks and impulses in a load path. EMs are textile devices typically manufactured out of nylon, Kevlar® and other materials, and control loads by breaking rows of stitches that bind a strong base webbing together as shown in Figure 1. A familiar EM application is a fall-protection harness used by workers to prevent injury from shock loads when the harness arrests a fall. EMs are also widely used in parachute systems to control shock loads experienced during the various stages of parachute system deployment.

Recent experience with a new EM designed for use in a parachute system revealed evidence of unexpected damage during operations. Numerous ground tests were conducted, which identified over 30 variables that could potentially contribute to the anomalous behavior. Over 4.6 million datapoints were collected. This large dataset required employment of an advanced statistical engineering technique, random forest, to understand which variables contributed most to the damage and could be considered for potential design changes.

Random forest is an innovative algorithm for data classification used in statistics and machine learning. It is an easy to use and highly flexible ensemble learning method. The random forest algorithm is capable of modeling both categorical and continuous data and can handle large datasets, making it applicable in many situations. It also makes it easy to evaluate the relative importance of variables and maintains accuracy even when a dataset has missing values.

Random forests model the relationship between a response variable and a set of predictor or independent variables by creating a collection of decision trees. Each decision tree is built from a random sample of the data. The individual trees are then combined through methods such as averaging or voting to determine the final prediction (Figure 2).

A decision tree is a non-parametric supervised learning algorithm that partitions the data using a series of branching binary decisions. Decision trees inherently identify key features of the data and provide a ranking of the contribution of each feature based on when it becomes relevant. This capability can be used to determine the relative importance of the input variables (Figure 3). Decision trees are useful for exploring relationships but can have poor accuracy unless they are combined into random forests or other tree-based models.

The performance of a random forest can be evaluated using out-of-bag error and cross-validation techniques. Random forests often use random sampling with replacement from the original dataset to create each decision tree. This is also known as bootstrap sampling and forms a bootstrap forest. The data included in the bootstrap sample are referred to as in-the-bag, while the data not selected are out-of-bag. Since the out-of-bag data were not used to generate the decision tree, they can be used as an internal measure of the accuracy of the model. Cross-validation can be used to assess how well the results of a random forest model will generalize to an independent dataset. In this approach, the data are split into a training dataset used to generate the decision trees and build the model and a validation dataset used to evaluate the model's performance. Evaluating the model on the independent validation dataset provides an estimate of how accurately the model will perform in practice and helps avoid problems such as overfitting or sampling bias. A good model performs well on both the training data and the validation data.

The complex nature of the EM system made it difficult for the team to identify how various parameters influenced EM behavior. A bootstrap forest analysis was applied to the test dataset and was able to identify five key variables associated with higher probability of damage and/or anomalous behavior. The identified key variables provided a basis for further testing and redesign of the EM system. These results also provided essential insight to the investigation and aided in development of flight rationale for future use cases.

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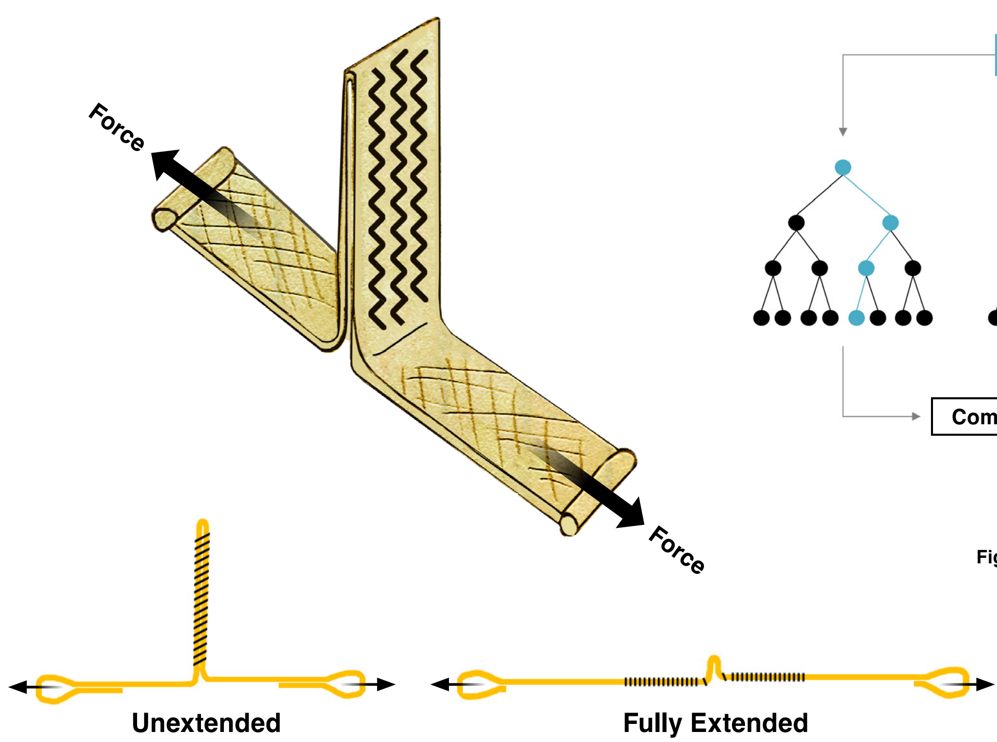


Figure 1. EMs are textile devices typically manufactured out of nylon, Kevlar and other materials, and control tensile loads by breaking rows of zigzag stitches that bind a strong base webbing together.

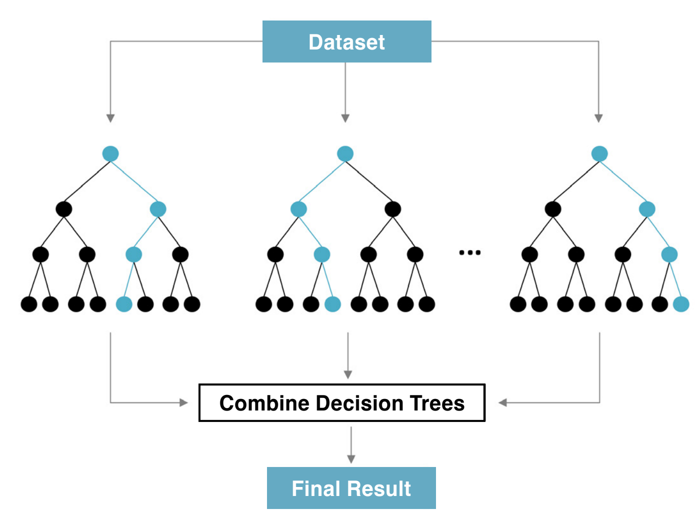
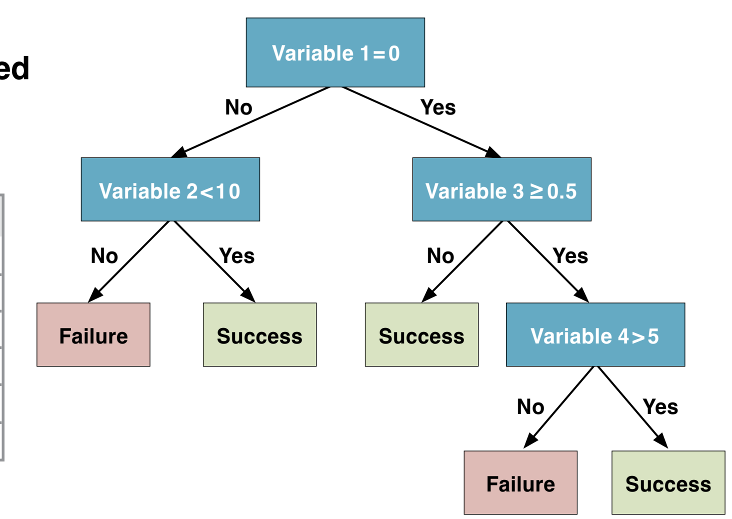


Figure 2. Random Forest

Statistical analysis conducted to identify key variables and combinations of variables related to higher probability of failure initiation

Bootstrap Forest Analysis	Variable Rankings	Contribution
Variable 1		0.6821
Variable 2		0.2308
Variable 3		0.0430
Variable 4		0.0221
Variable 5		0.0220
Variable 6		0.0000



- ***Bootstrap forest analysis used to generate 10,000 decision trees***
- ***Each tree grown from a random sample of the database***
- ***Average across trees to make predictions***

Figure 3. Example of decision tree and variable rankings from bootstrap forest

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Contact Dynamics Predictions Utilizing the NESC Parameterless Contact Model

Modeling the capture of the Mars Sample Return (MSR) Orbiting Sample (OS) involves understanding complex dynamic behavior, which includes the OS making contact against the interior of the capture enclosure. The MSR Program required numerical verification of the contact dynamics' predictions produced using their commercial software tools. This commercial software used "free" parameters to set up the contact modeling. Free parameters (also known as free variables) are not based on contact physics. The commercial contact model used by MSR required seven free parameters including a Hertzian contact stiffness, surface penetration, stiffening exponent, penetration velocity, contact damping, maximum penetration depth for the contact damping value, and a smoothing function. An example of a parameter that is not free is coefficient of friction, which is a physics-based parameter. Consider the free parameter, contact stiffness. Contact stiffness is already present in the finite element model's (FEM) stiffness matrix where the bodies come into contact, and surface penetration is disallowed in a physically realizable contact model, as FEM meshes should not penetrate one another during contact (i.e., the zero-contact limit penetration constraint condition). As such, with each set of selected free parameters generating a different contact force signature, additional numerical verification is required to guide setting these parameters.

Contact modeling is nonlinear. This means that the stiffness matrices of contacting bodies are continuously updated as the bodies come into contact, potentially recontact (due to vibrations), and disengage. The modal properties of contacting bodies continuously change with state transitions (e.g., stick-to-slip). Some contact models have been proposed and incorporated in commercial finite element analysis solvers, and most involve static loading. A relatively smaller number involve dynamics, which has historically proven challenging. In 2005, NASA conducted a study testing several commercial contact solvers in predicting contact forces in transient dynamic environments. This was necessitated by the Space Shuttle Program (SSP)—after the February 2003 Columbia accident—deciding to include contact dynamics in the Space Shuttle transient coupled loads analysis (CLA) to capture the impact of contact nonlinearities. This rendered the entire CLA nonlinear. The study found major difficulties executing nonlinear CLAs in commercial software. A nonlinear solver developed by the NESC and Applied Structural Dynamics (ASD) that was able to produce physically realizable results was numerically verified by NASA and later experimentally validated as well. This nonlinear solver was subsequently utilized to execute all NASA SSP CLAs (i.e., crewed space flights) from 2005 to the final flight in 2011, as well as currently supporting the SLS Program. The objective of the MSR contact verification work was to provide data that could be used by the MSR team to help define the free parameters listed above for the commercial tool contact model. The NESC/ASD solver was used to model contact between simple cantilever and free beams, deriving contact forces and relative displacements. These resulting data can be used to determine parameter values for more complex structures. Two of the modeled configurations, one for axial contact (Figure 1) and the other for stick/friction (Figure 2), and sample results from the NESC nonlinear dynamic analyses are presented in Figures 1 and 2.

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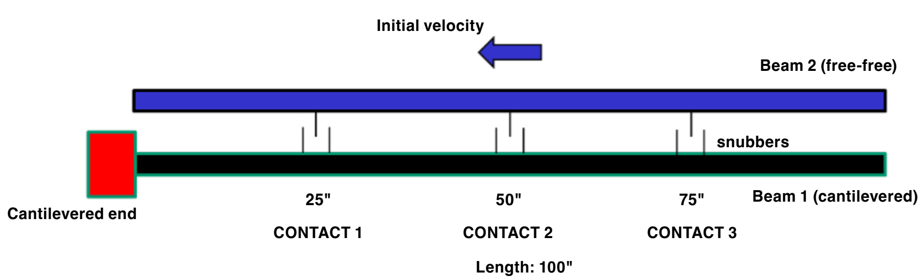


Figure 1a. Free-free beam contacting cantilevered beam at three snubbers.

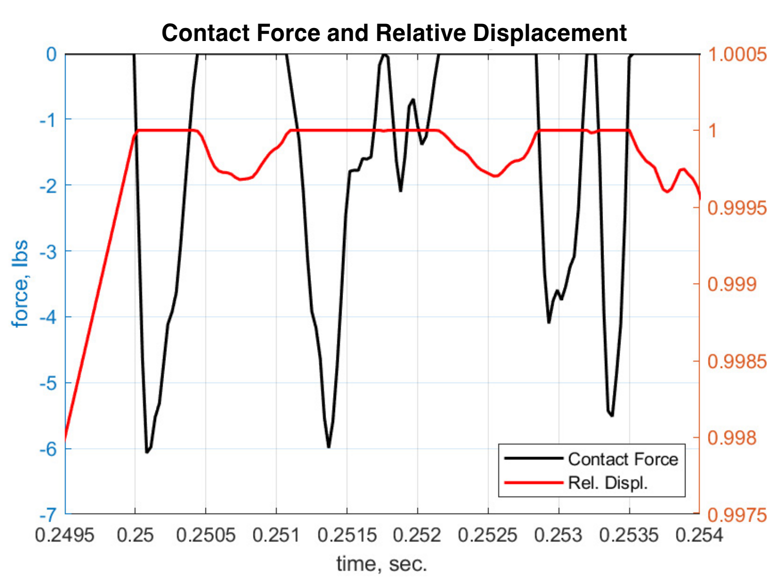


Figure 1. Contact Force and Relative Displacement Time-History at Contact 1 Demonstrating High Frequency Vibrations as well as Multiple Recontacts. (A Relative Displacement of 1.0 signifies surfaces are in contact).

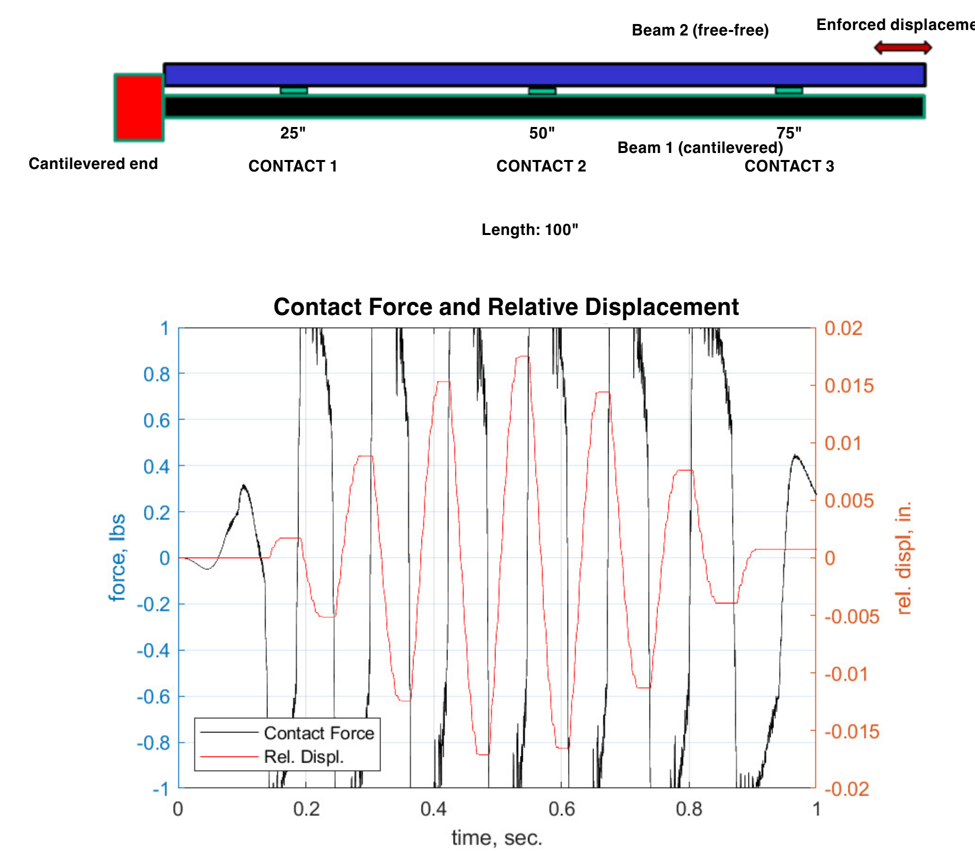


Figure 2. Contact Force and Relative Displacement Time-History at Contact Surface 3 Showing Distinct Regions of Stiction and Sliding Friction as well as Transients due to Transition from Slip to Stick.

DISCIPLINE FOCUS

Discipline Perpectives Related to NESC Technical Activities

This section highlights work from thermal control & protection, human factors, materials, and mechanical systems disciplines—just some of the work the NASA Technical Fellows and their TDTs engaged in this year and how their work contributes to the advancement of their disciplines.

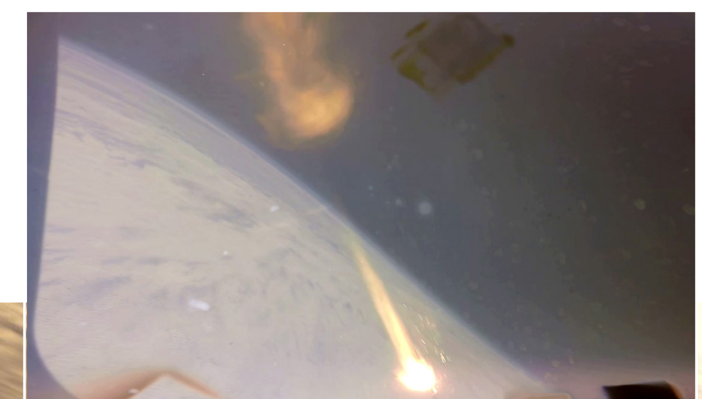
> The NESC sustains a network of more than 1,100 engineers across 20 different disciplines who can be called on for NESC assessments.
>
> - Aerosciences
> - Avionics
> - Cryogenics
> - Electrical Power
> - Environmental Control & Life Support
> - Flight Mechanics
> - Guidance, Navigation, & Control
> - Human Factors
> - Loads & Dynamics
> - Materials
> - Mechanical Systems
> - Nondestructive Evaluation
> - Nuclear Power & Propulsion
> - Propulsion
> - Sensors & Instrumentation
> - Software
> - Space Environments
> - Structures
> - Systems Engineering
> - Thermal Control & Protection

Thermal Control & Protection

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

NESC ASSISTS IN HEATSHIELD INVESTIGATION

NASA's uncrewed Artemis I mission launched from KSC on November 16, 2022. After a successful mission that included orbiting the Moon, the Orion spacecraft returned to Earth splashing down in the Pacific Ocean on December 11, 2022. While the spacecraft made a safe return to Earth, postflight inspection of Orion's thermal protection indicated that the base heatshield did not perform as expected. The heatshield is composed of Avcoat, an ablative material designed to protect the crew module during the nearly 5000°F temperatures experienced during atmospheric entry upon return from the Moon. Specifically, inspection revealed more than 100 locations where the charred Avcoat material chipped away from the heatshield.

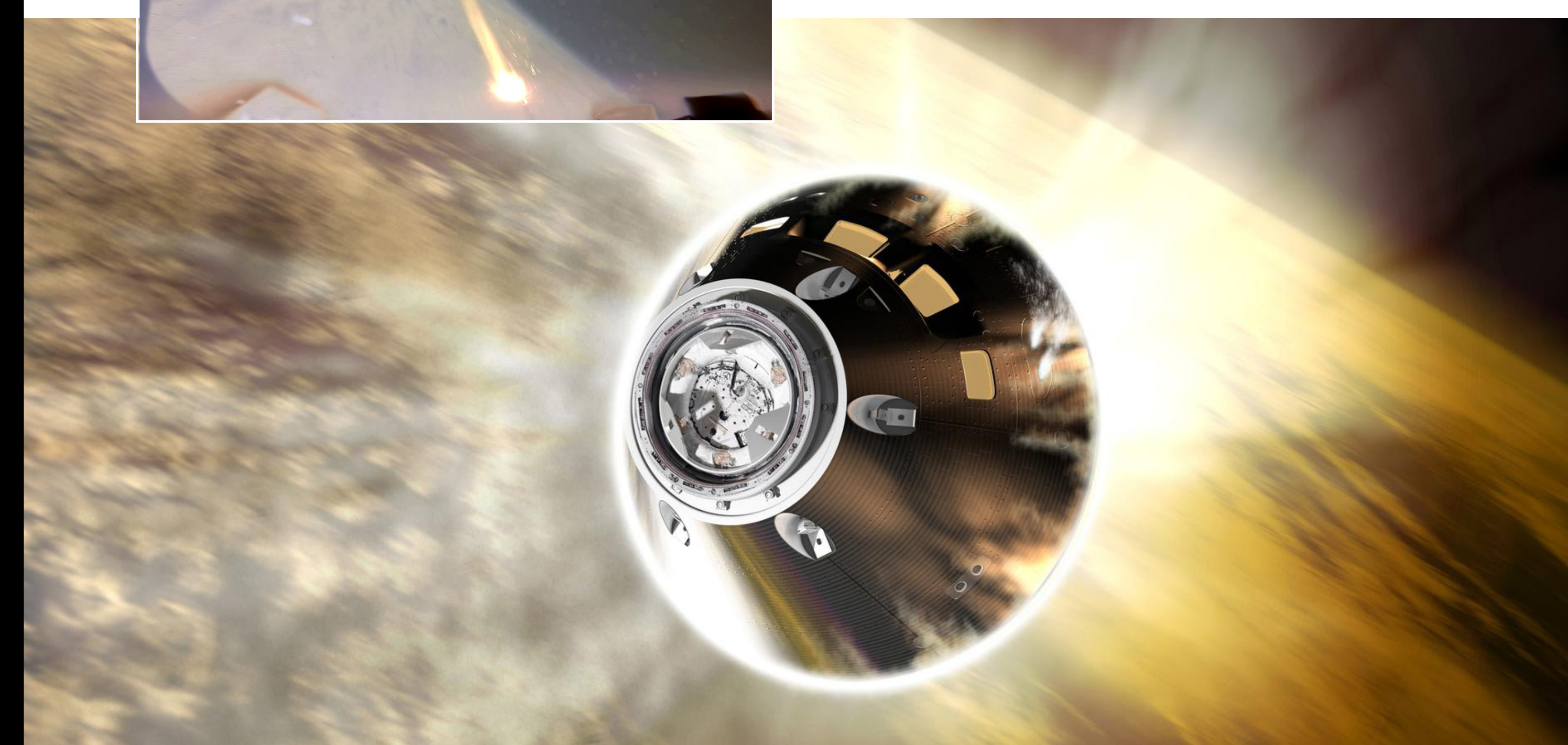


The NESC formed a team of subject matter experts from across and outside of the Agency to assist the Orion Program team in the overall investigation. NESC team members are supporting or leading efforts in multi-physics analysis, material testing, fault tree and root cause analysis, aeroscience review, analysis peer review, nondestructive evaluation (NDE), as well as investigation of alternative heatshield concepts.

The NESC works closely with the Artemis I Char Loss Team to ensure the observed material loss is thoroughly understood so that decisions may be made regarding use for upcoming crewed missions. To date, NESC contributions have included pathfinding NDE techniques for postflight heatshield inspection, investigation of key Avcoat material properties and behavior, and providing key inputs to the fault tree development and disposition to guide a thorough investigation of possible causes.

Left: View from Artemis I crew cabin window showing material loss during entry (foreground).

Below: An artist's illustration of Orion crew module entering the Earth's atmosphere.



Human Factors

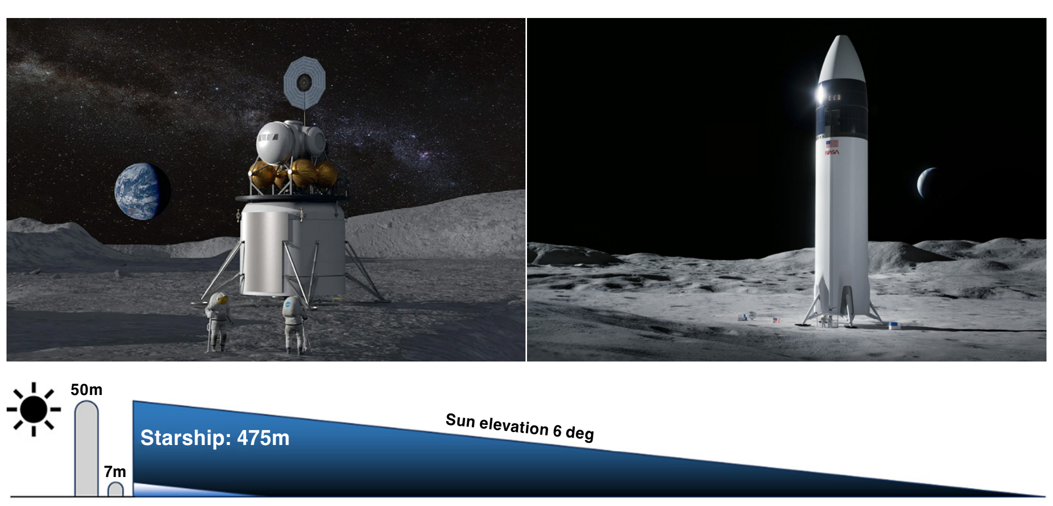
Dr. Cynthia H. Null
NASA Technical Fellow for Human Factors

CHARACTERIZING THE VISUAL EXPERIENCE OF ASTRONAUTS AT THE LUNAR SOUTH POLE

Humans are returning to the Moon—this time, to stay. Because our presence will be more permanent, NASA has selected a location that maximizes line-of-sight communication with Earth, solar visibility, and access to water ice: the Lunar South Pole (LSP). While the Sun is in the lunar sky more consistently at the poles, it never rises more than a few degrees above the horizon; in the target landing regions, the highest possible elevation is 7°. This presents a harsh lighting environment never experienced during the Apollo missions, or in fact, in any human spaceflight experience. The ambient lighting will severely affect the crews' ability to see hazards and to perform simple work. This is because the human vision system, which despite having a high-dynamic range, cannot see well into bright light and cannot adapt quickly from bright to dark or vice versa. Functional vision is required to perform a variety of tasks, from simple tasks (e.g., walking, operating simple tools) through managing complex machines (e.g., lander elevator, rovers). Thus, the environment presents an engineering challenge to the Agency: one that must be widely understood before it can be effectively addressed.

In past NASA missions and programs, design of lighting and functional vision support systems for extravehicular activity (EVA) or rover operations have been managed at the lowest program level. This worked well for Apollo and low Earth orbit because the Sun angle was managed by mission planning and astronaut self-positioning; helmet design alone addressed all vision challenges. The Artemis campaign presents new challenges to functional vision, because astronauts will be unable to avoid having the sun in their eyes much of the time they are on the lunar surface. This, combined with the need for artificial lighting in the extensive shadowing at the LSP, means that new functional vision support systems must be developed across projects and programs. The design of helmets, windows, and lighting systems must work in a complementary fashion, within and across programs, to achieve a system of lighting and vision support that enables crews to see into darkness while their eyes are light-adapted, in bright light while still dark-adapted, and protects their eyes from injury.

The NESC performed an assessment to better understand and characterize the visual experience of astronauts in the harsh lighting environment and to provide recommendations to the programs participating in surface operations regarding the constraints on functional human vision these new environments will impose. The assessment focused on the Apollo experience, LSP natural environments, human visual capabilities, existing spaceflight standards and programmatic requirements, and Agency and non-NASA simulation capabilities.

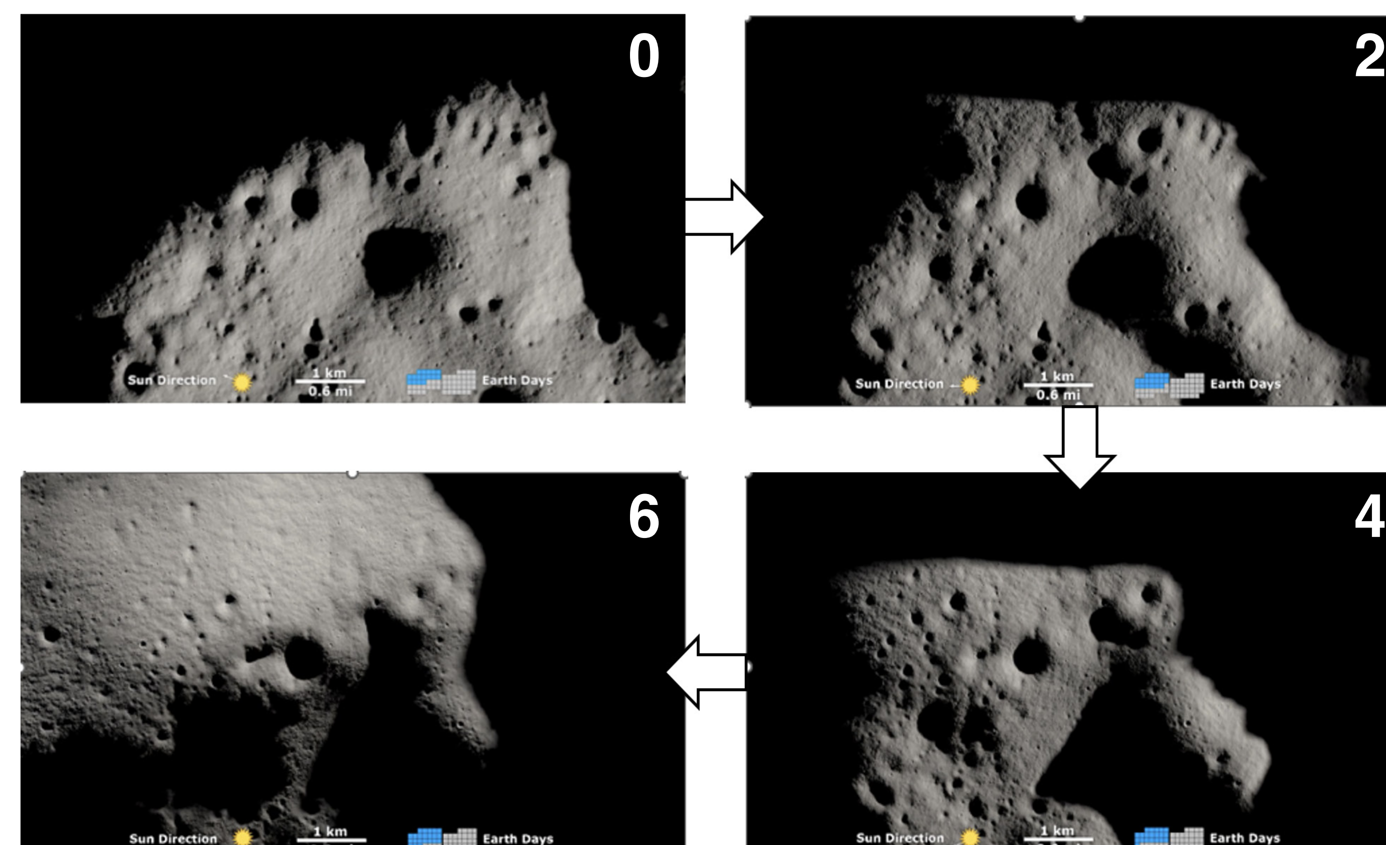


Examples of artists' concepts of future moon landings carried out under NASA's Artemis Program (top). These renderings do not accurately depict the shadows that astronauts will experience at the LSP, and thus they give an impression of the visual experience that is unrealistic. For comparison, shadow lengths are shown for the SpaceX Starship vehicle and the Apollo 12 Lunar Module when the Sun elevation is 6 degrees above the horizon (bottom). Image credits: NASA (top left); SpaceX (top right).

Many of the findings of the assessment were focused on the lack of specific requirements to prevent functional vision impairment by the Sun's brilliance (which is different from preventing eye injury), while enabling astronauts to see well enough to perform specific tasks. Specifically, tasks expected of astronauts at the LSP were not incorporated into system design requirements to enable system development that ensures functional vision in the expected lighting environment. Consequently, the spacesuit, for example, has flexibility requirements for allowing the astronauts to walk but not for ensuring they can see well enough to walk from brilliant Sun into a dark shadow and back without the risk of tripping or falling. Importantly, gaps were identified in allocation of requirements across programs to ensure that the role of the various programs is for each to understand functional vision. NESC recommendations were offered that made enabling functional vision in the harsh lighting environment a specific and new requirement for the system designers. The recommendations also included that lighting, window, and visor designs be integrated.

The assessment team recommended that a wide variety of simulation techniques, physical and virtual, need to be developed, each with different and well-stated capabilities with respect to functional vision. Some would address the blinding effects of sunlight at the LSP (not easily achieved through virtual approaches) to evaluate performance of helmet shields and artificial lighting in the context of the environment and adaptation times. Other simulations would add terrain features to identify the threats in simple (e.g., walking, collection of samples) and complex (e.g., maintenance and operation of equipment) tasks. Since different facilities have different strengths, they also have different weaknesses. These strengths and limitations must be characterized to enable verification of technical solutions and crew training.

Apollo 12; the lander with the sun in the field of view, illustrating the challenges to functional vision (the photographic flare does not represent the actual size of the sun). In Artemis landings, the sun will always be below this elevation.



Simulated terrain at LSP shows lighting change progression for the same lunar surface area over 6 Earth days, depicting how low-angle lighting changes can dramatically affect how the lunar surface is perceived. Image credits: NASA's Goddard Space Flight Center Scientific Visualization Studio.

Materials

Dr. Bryan W. McEnerney
NASA Technical Fellow for Materials

COLLABORATION IS KEY TO A STRONG MATERIALS DISCIPLINE

NASA has a strong need for advanced materials and processes (M&P) across the realms of robotic- and crewed-spaceflight, as well as aeronautics, particularly when one acknowledges that all craft must be made of something. To meet that need, the materials discipline relies on collaboration—both between centers and across disciplines. Reaching the Agency's Moon-to-Mars objectives will require leveraging each center's specific M&P expertise, cross-training among the centers, and routinely interacting with the 20-plus Agency disciplines like structures, space environments, and loads and dynamics. When a discipline touches all classes of materials; all aspects of design, manufacturing, testing, and operations; and all phases of flight, collaboration is the only way to broaden and deepen its reach.

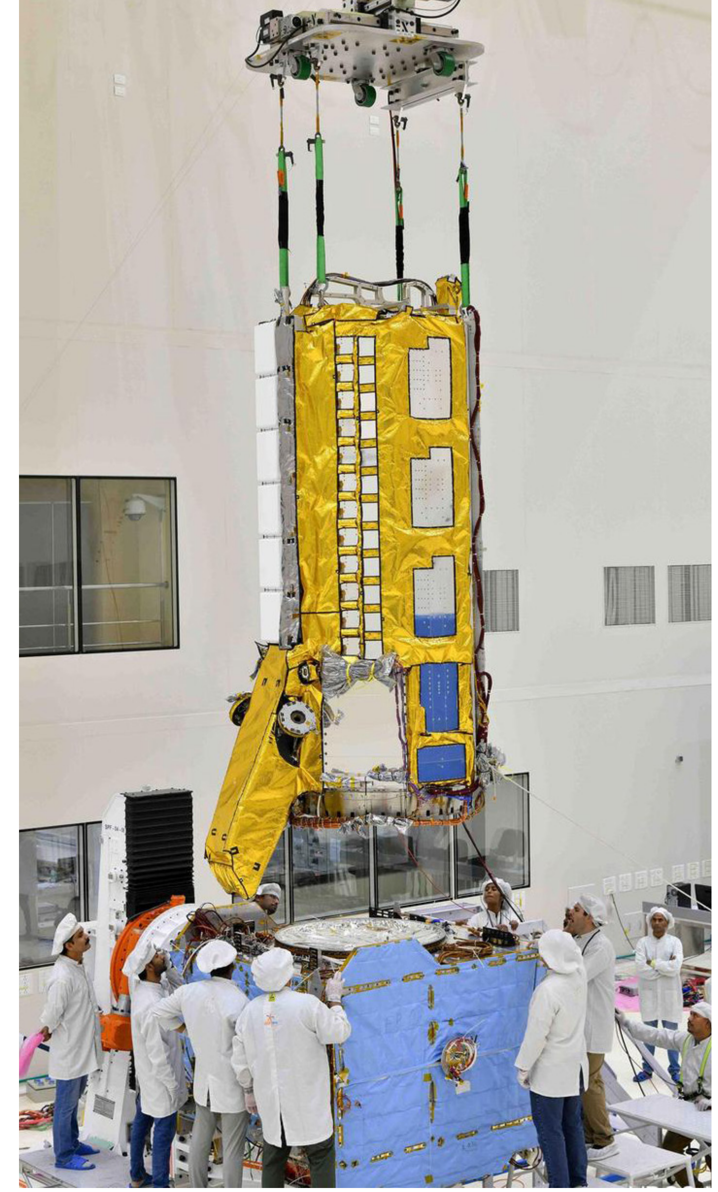
This year, the Materials TDT pulled in wide-ranging center and discipline support for the VIPER lunar rover, investigations of cracks in the ISS Russian PrK, the X-59 supersonic aircraft, and the SLS Program. It also leveraged its contamination control experience to aid the Commercial Crew and Orion Programs. Below are some additional highlights from the year.

Collaboration Among Disciplines

Ms. Alison Park, NASA Deputy Technical Fellow for Materials, led a multi-disciplinary NESC team to address JPL's request for support to investigate anomalous temperature readings during thermal vacuum testing of the NASA Indian Space Research Organisation (ISRO) Synthetic Aperture Rader (NISAR) reflect-array hardware, already integrated onto the spacecraft in India. The team provided detailed reviews of the thermal models and supported materials testing and characterization of the reflect-array construction record. The team's work identified operability concerns from higher-than-expected temperatures that would be seen during the multi-day deployment process. The hardware was demated from the spacecraft and returned to the United States for design upgrades and modifications to address the new concerns. The hardware is now set to return to India for reintegration and final launch preparations.

"No one person could be an expert in all facets of our discipline."

\- Dr. Bryan McEnerney



Fostering Intercenter Cooperation

Mr. Robert Carter, NASA Deputy Technical Fellow for Materials and GRC Deputy Division Chief, attended a technical exchange between GRC and MSFC. The exchange uncovered the need for an Agency-wide, materials-driven alloy development plan to identify key needs that would benefit spaceflight and aeronautics.

From there, materials representatives from 7 of the 10 centers met in-person to develop a roadmap and a plan to be released in FY25. The Materials TDT also stood up an Alloy Development Community of Practice to provide a grassroots mechanism to identify cross-Agency needs, technical challenges, and benefits that aren't identified programmatically or within mission directorates.

Leveraging NASA Partnerships

The NASA Technical Fellow for Materials, Dr. Bryan W. McEnerney, hosted visitors from the European Space Agency (ESA) for a combined trip to JPL, GRC, and KSC, as well as the jointly organized Worldwide Advanced Manufacturing Symposium (WAMS) in Orlando, FL. In-depth technical interchanges between NASA and ESA emphasized advanced manufacturing with a focus on spaceflight needs. The event increased technical collaboration between the two organizations, leading to ESA's request to NASA for a formal review of ESA's stress corrosion standard. Work was also initiated on a joint NASA/ESA intern program.

Next year brings a number of new and exciting challenges, including an elevated temperature testing program focused on Hall-Petch effects in C-103 (niobium alloy), the domestic North American WAMS symposium in Knoxville, TN, and a continued focus on intercenter technical support. And, always a key objective, the discipline will actively engage early-career personnel on NESC assessments to learn from our veteran materials experts and to pass on the knowledge so unique to the space industry.

Top left: Illustration depicting the NISAR satellite in orbit over central and Northern California. The satellite features an advanced radar system to globally monitor changes to Earth's land and ice surfaces to deepen scientists' understanding of natural hazards, land use, climate change, and other global processes. Top right: In June 2023, NISAR's radar instrument payload and spacecraft bus were combined in an ISRO clean room facility in Bengaluru, India. Image credit: VDOS-URSC. Bottom: Alloy Development community of practice participants. Robert Carter is at center.

Mechanical Systems

Dr. Michael J. Dube
NASA Technical Fellow for Mechanical Systems

MECHANICAL SYSTEMS TDT SUPPORT REACHES ACROSS NASA PROGRAMS

The NESC Mechanical Systems TDT provides broad support across NASA's mission directorates. We are a diverse group representing a variety of sub-disciplines including bearings, gears, metrology, lubrication and tribology, mechanism design, analysis and testing, fastening systems, valve engineering, actuator engineering, pyrotechnics, mechatronics, and motor controls. In addition to providing technical support, the TDT owns and maintains NASA-STD-5017, "Design and Development Requirements for Space Mechanisms."

Mentoring the Next Generation

The NESC Mechanical Systems TDT actively participates in the Structures, Loads & Dynamics, Materials, and Mechanical Systems (SLAMS) Early Career Forum that mentors early-career engineers. The TDT sent three members to this year's forum at WSTF, where early-career engineers networked with peers and NESC mentors, gave presentations on tasks they worked on at their home centers, and attended splinter sessions where they collaborated with mentors.

New NASA Valve Standard to Reduce Risk and Improve Design and Reliability

Valve issues have been encountered across NASA's programs and continue to compromise mission performance and increase risk, in many cases because the valve hardware was not qualified in the environment as specified in NASA-STD-5017. To help address these issues, the Mechanical Systems TDT is developing a NASA standard for valves. The TDT assembled a team of subject matter experts from across the Agency representing several disciplines including mechanisms, propulsion, environmental control and life support systems, spacesuits, active thermal control systems, and materials and processes. The team has started their effort by reviewing lessons learned and best practices for valve design and hope to have a draft standard ready by the end of 2025.

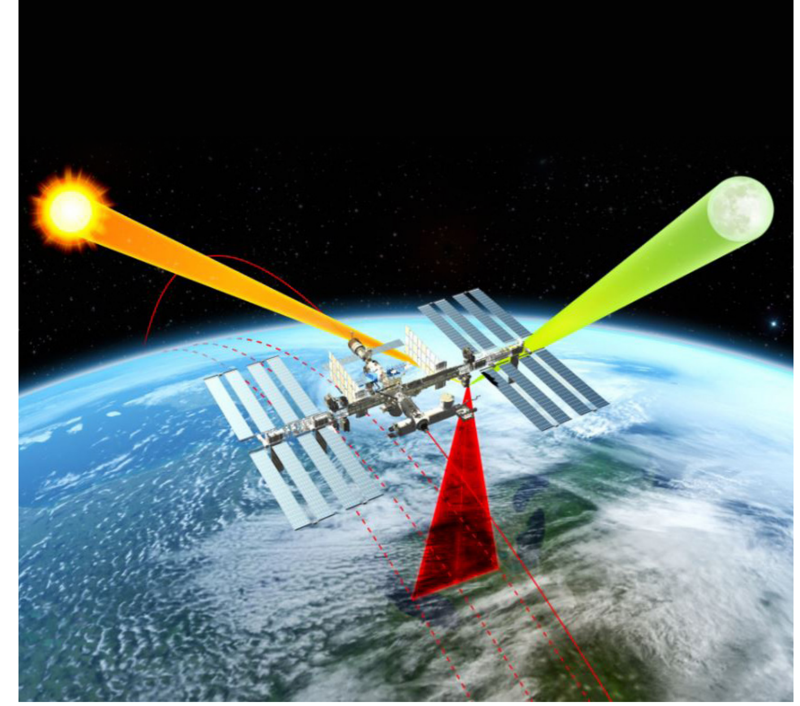
Bearing Life Testing for Reaction Wheel Assemblies

The Mechanical Systems TDT just concluded a multiyear bearing life test on 40 motors, each containing a pair of all steel bearings of two different conformities or a pair of hybrid bearings containing silicon nitride balls. The testing confirmed that hybrid bearings outperformed their steel counterparts, and bearings with higher conformity (54%) outperformed bearings with lower conformity (52%). The team is disassembling and inspecting the bearings, and initial results have been surprising. The TDT was able to "recover" some of the bearings that failed during the life test and get them running as well as they did when testing began. Some bearings survived over five billion revolutions and appeared like new when they were disassembled and inspected. These results will be published once analysis is complete.

X-57 Design Assessment

The Mechanical Systems TDT was asked by the Aeronautics Mission Directorate to assess the design of the electric cruise motors installed on X-57. The team responded quickly to meet the Project's schedule, making an onsite visit and attending numerous technical interchange meetings. After careful review of the design, the TDT identified areas for higher-level consideration and risk assessment and attended follow-on reviews to provide additional comments and advice.

Attendees gathered at the 13th annual NASA SLAMS Early Career Forum, July 2024.



An illustration of how CLARREO Pathfinder will take measurements of Earth (red) and use the Sun (orange) and Moon (green) for regular instrument calibration on ISS.

NASA's all-electric X-57 Maxwell at AFRC.

NASA's Perseverance Mars rover selfie taken in July 2024.

CLARREO Pathfinder Inner Radial Bearing Anomaly

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder was designed to take highly accurate measurements of reflected solar radiation to better-understand Earth's climate. During payload functional testing, engineers detected a noise as the HySICS pointing system was rotated from its normal storage orientation. Mechanical Systems TDT members reviewed the design and inspection reports after disassembly of the inner bearing unit, noticing contact marks on the bore of the inner ring and the shaft that confirmed that the inner ring of the bearing was moving on the shaft with respect to the outer ring. Lubricant applied to this interface resolved the noise problem and allowed the project to maintain schedule without any additional costs.

JPL Wheel Drive Actuator Extended Life Test Independent Review Team

A consequence of changes to its mission on Mars will require the Perseverance Rover to travel farther than originally planned. Designed to drive 20 km, the rover will now need to drive ~91 km to rendezvous and support Mars sample tube transfer to the Sample Retrieval Lander. The wheel drive actuators with integral brakes had only been life tested to 40 km, so a review was scheduled to discuss an extended life test. The OCE Science Mission Directorate Chief Engineer assembled an independent review team (IRT) that included NESC Mechanical Systems TDT members. This IRT issued findings and guidance that questioned details of the JPL assumptions and plan. Several important recommendations were made that improved the life test plan and led to the identification of brake software issues that were reducing brake life. The life test has achieved 40 km of its 137 km goal and is ongoing. In addition, software updates were sent to the rover to improve brake life.

Orion Crew Module Hydrazine Valve

When an Orion crew module hydrazine valve failed to close, the production team asked the Mechanical Systems TDT for help. A TDT member attended two meetings and then visited the valve manufacturer, where it was determined this valve was a scaled-down version of the 12-inch SLS prevalve that was the subject of a previous NESC assessment and shared similar issues. The Orion Program requested NESC materials and mechanical systems support. The Mechanical Systems TDT member then worked closely with a Lockheed Martin (LM) Fellow for Mechanisms to review all the valve vendor's detailed drawings and assembly procedures and document any issues. A follow-on meeting was held to brief both the LM and NASA Technical Fellows for Propulsion that a redesign and requalification was recommended. These recommendations have now been elevated to the LM Vice President for Mission Success and the LM Chief Engineer for Orion.

NESC HONOR AWARDS

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

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

Left to right: Front row - Nga Pham (Jenlyn Solutions), Charles Dischinger (MSFC Retiree), John Puryear (Applied Physical Sciences Corporation), Timothy Wray (MSFC), Brian Tulaba (Jacob's Technology, Inc.); Second row - David J. Alexander (JSC), Ari Brown (GSFC), Stephen Scotti (LaRC), David Dawicke (Analytical Services & Materials, Inc.), Jesse Couch (Adaptive Aerospace Group, Inc.), Joseph Anderson (JSC), James Bontempo (Analytical Mechanics Associates)

NESC Director's Award

Honors individuals for defending a technical position that conflicts with a program or organization's initial or prevailing engineering perspectives and for taking personal initiative to foster clear and open communication and resolve controversial issues.

David J. Alexander - In recognition of his determination to communicate critical concerns with spacesuit helmet washout performance test methods, analysis, and interpretation.

NESC Leadership Award

Honors individuals for sustained leadership excellence demonstrated by establishing a vision, developing and managing a plan, and building consensus to proactively resolve conflicts and achieve results.

H. Charles Dischinger - In recognition of outstanding leadership and sustained commitment to the NESC Human Factors Technical Discipline Team.

NESC Engineering Excellence Award

Honors individuals for making significant engineering contributions, developing innovative approaches, and ensuring appropriate levels of engineering rigor are applied to the resolution of technical issues in support of the NESC mission.

Joseph B. Anderson - In recognition of engineering excellence and technical expertise employed to abate the Orion flywheel exercise device acoustic emissions.

Michael A. Beamesderfer - In recognition of engineering excellence and technical leadership in conducting the Assessment of Degradation in Microfabricated Detectors and MEMS Devices.

Richard Blank - In recognition of engineering excellence in investigating the Commercial Crew Program pyro initiator lot acceptance test failure.

James J. Bontempo - In recognition of engineering excellence in technical analysis and problem resolution to some of NASA's most challenging issues in human spaceflight.

Ari D. Brown - In recognition of engineering excellence and technical leadership in conducting the Assessment of Degradation in Microfabricated Detectors and MEMS Devices.

Jesse C. Couch - In recognition of engineering excellence in the development and analysis of an innovative and cost-effective solution to improve crew safety by reducing Commercial Crew Program software erroneous output risk.

Edward B. Jackson - In recognition of engineering excellence and technical leadership in establishing innovative approaches and applying sound engineering rigor in analyzing the Commercial Crew Program software erroneous output risk.

Karl T. Kahre - In recognition of engineering excellence for the rigorous development of Artemis I and II test-based loads predictions for the Orion Crew Module Uprighting System.

Jayanta Panda - In recognition of engineering excellence in the innovative implementation of a microphone phased array demonstrating the feasibility to measure launch-vehicle engine acoustic energy intensity.

John M. Puryear - In recognition of engineering excellence in the development of a continuous multibody uprighting model of the Orion Crew Module with wave coupling and soft goods deformability.

Stephen J. Scotti - In recognition of engineering excellence in the development and execution of analyses and test approaches for the Orion Heat Shield Char Loss Investigation.

Brian K. Tulaba - In recognition of engineering excellence demonstrated in the development of micrometeoroid and orbital debris risk assessments for the Mars Sample Return Capture, Containment, and Return System.

Timothy J. Wray - In recognition of engineering excellence in the evaluation of methods and measurement uncertainty for dynamics-based liquid mass gauging.

NESC Administrative Excellence Award

Honors individual accomplishments that contributed substantially to support the NESC mission.

Ella Mamtsis - In recognition of exceptional leadership in the NESC Portal redesign project exhibited by driving quality outputs, ensuring stakeholder alignment, and promoting cross-functional teamwork.

NESC Group Achievement Award

Honors a team of employees comprising government and non-government personnel. The award is in recognition of outstanding accomplishment through the coordination of individual efforts that have contributed substantially to the success of the NESC mission.

Unconservatism of Linear-Elastic Fracture Mechanics Analysis Post-Autofrettage Assessment Team - In recognition of outstanding technical achievement in the evaluation of compressive stresses in thin-walled COPVs and the relationship to liner damage tolerance.

NESC Portal Integration Team - In recognition of outstanding achievement in the development and redesign of the NESC Portal.

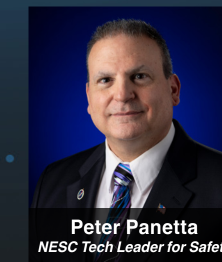
OFFICE OF THE DIRECTOR


Timmy R. Wilson
NESC Director


Michael T. Kirsch
NESC Deputy Director


Mary Elizabeth Wusk
NIO Manager

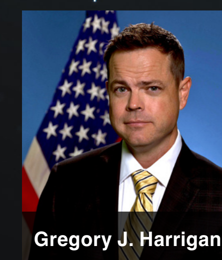

Lisa A. McAlhaney
MTSO Manager

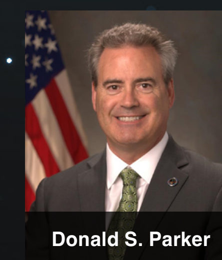

Peter Panetta
NESC Tech Leader for Safety

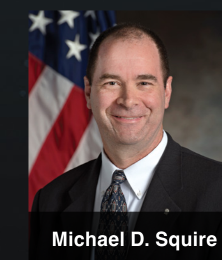

Mark T. Vande Hei
NESC Chief Astronaut

NESC PRINCIPAL ENGINEERS

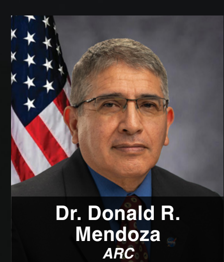

Jon P. Haas

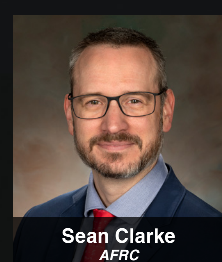

Gregory J. Harrigan


Donald S. Parker


Michael D. Squire

NESC CHIEF ENGINEERS


Dr. Donald R. Mendoza
ARC


Sean Clarke
AFRC

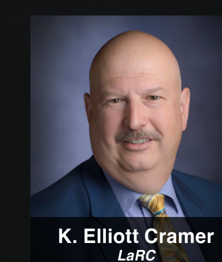

Robert S. Jankovsky
GRC


Carmel A. Conaty
GSFC


Kimberly A. Simpson
JPL


Joel W. Sills
JSC

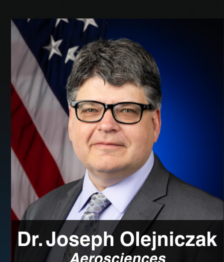

Stephen A. Minute
KSC


K. Elliott Cramer
LaRC


Steven J. Gentz
MSFC


Michael D. Smiles
SSC

NASA TECHNICAL FELLOWS


Dr. Joseph Olejniczak
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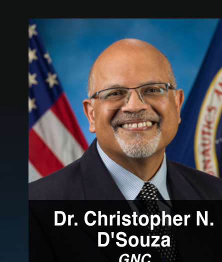
Dr. Robert F. Hodson
Avionics


Michael L. Meyer
Cryogenics

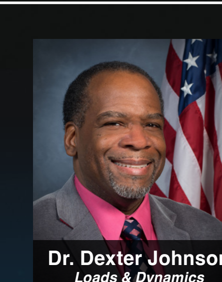

Dr. Christopher J. Iannello
Electrical Power


Dr. Morgan B. Abney
Environmental Control & Life Support


Heather M. Koehler
Flight Mechanics


Dr. Christopher N. D'Souza
GNC


Dr. Cynthia H. Null
Human Factors


Dr. Dexter Johnson
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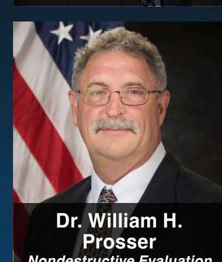
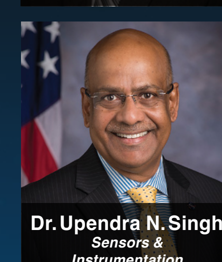
Dr. Bryan W. McEnerney
Materials


Dr. Michael J. Dube
Mechanical Systems


Dr. William H. Prosser
Nondestructive Evaluation


Dr. Jonathan E. Jones
Propulsion


Dr. Upendra N. Singh
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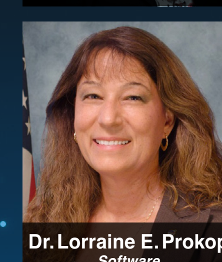
Dr. Lorraine E. Prokop
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Dr. Joseph I. Minow
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Deneen M. Taylor
Structures


Jon B. Holladay
Systems Engineering


Steven L. Rickman
Thermal Control & Protection

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David Francisco, Office of the Chief Health and Medical Officer (OCHMO)
Glen W. Lockwood, Office of Safety and Mission Assurance (OSMA)

Full Bios at NASA.GOV/NESC

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Barry E. Wilmore
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Dr. Daniel Winterhalter
NESC Chief Scientist (2005-20)

In Memory of Dr. Charles E. Harris

NESC Principal Engineer (2003-06)

Charlie passed away peacefully on January 30, 2024. He spent the bulk of his career at LaRC, ultimately leading research operations for the entire Center. He applied his vast wealth of knowledge to the Space Shuttle Return to Flight initiative, which uncovered the root cause of the 2003 Columbia Space Shuttle accident—work that enabled the resumption of the Space Shuttle Program. He served as NESC Principal Engineer from 2003-2006. In 2007, President George W. Bush named Charlie a Distinguished Executive in the federal government's Senior Executive Service. Our colleague, friend, and mentor will be greatly missed.

Publications Based on NESC Activities

Technical Papers, Conference Proceedings, and Technical Presentations

AVIONICS

1. Gaza, R., Allen, G., Campola, M., Label, K., Ladbury, R., Lauenstein, J. M., Pritts, J., Wilcox, E., Majewicz, P., & Hodson, R. (2024, September 16-20). The NASA Radiation Hardness Assurance (RHA) Process Standard. The RADiation Effects on Components and Systems (RADECS 2024) Conference.
2. Loveless, A., Hodson, R. F., Torres-Pomales, W., & Miner, P. S. (2024, July). Failure-Tolerant Avionics for Crewed Space Systems. IEEE Space Mission Challenges for Information Technology/Space Computing Conference, Mountain View, CA.

CRYOGENICS

1. Meyer, M. L., Johnson, W. J., Stephens, J. R., Nugent, B. T., Hauser, D. M., & Kassemi, M. (2024, July 22-26). NASA's Progress Maturing Zero Boil-off Technology to Enable Long-Duration Space Missions with Cryogenic Propellants. 29th International Cryogenic Engineering Conference/International Cryogenic Materials Conference.
2. Meyer, M. L. (2024, August 26-30). Mastering Cryogenic Propellants for Space Applications: Introduction to Cryogenic Fluid Management. Thermal and Fluids Analysis Workshop.

ECLSS

1. Abney, M., Wilson, S., Pitts, R., Peterson, E., Bhattacharyya, D., Lipscomb, G., Reeder, J., & Steele, J. (2024, July 21-25). Assessment of Performance Degradation of the Spacesuit Water Membrane Evaporator (SWME) Materials due to Environmental Conditions. ICES-2024-463, 53rd International Conference on Environmental Systems.
2. Jones, R., Abney, M., Brady, T., McFarland, S., Rhodes, R., Funk, A., Wilson, S., Morris, D., Stephens, C., & Deaton, A. (2024, July 21-25.). Validation Testing and Statistical Analysis of the Rotary Tumbler Fabric Abrasion Method. 53rd International Conference on Environmental Systems.
3. Campbell, C., Buhler, C., Toth, J.R.III, Abney, M. (2024, July 21-25). Electrostatic Discharge Hazard in Spacesuits. 53rd International Conference on Environmental Systems, ICES-2024-475, Louisville, KY.
4. Jones, R.J., Abney, M.B., Brady, T., Morris, D., Rhodes, R., McFarland, S., Cox, D., Settles, J., Funk, A. (2024, July 21-25). Establishing a Standardized Test Method for Evaluating the Cut Resistance of Space Suit Glove Fabrics. 53rd International Conference on Environmental Systems, ICES-2024-52, Louisville, KY.
5. Abney, M.B., Simpkins, P., Provin, T., Willard, D., Santamaria, R., Chen, Y., Weislogel, M., Dietrich, D., Urban, D., Williams, D., Goetter, C., Harper, S., Juarez, A. (2024, July 21-25). Predicting the Microgravity Performance of Terrestrial Portable Fire Extinguishers. 53rd International Conference on Environmental Systems, ICES-2024-461, Louisville, KY.
6. Campbell, C., Peralta, S., Ward, V., Gallus, T., Morris, D., Abney, M. (2024, July 21-25). Wire-break Ignition Testing of Materials for Spacesuit Fire Hazard Control. 53rd International Conference on Environmental Systems, ICES-2024-476, Louisville, KY.

GUIDANCE, NAVIGATION, AND CONTROL

1. Benson, W., Dennehy, C., Marsell, B, VanZwieten, T., Orr, J. (2024). Low-G Slosh Workshop Results From 2023: State of the Art, Gaps and Forward Work. 46th Annual AAS Guidance, Navigation and Control (GNC) Conference, Breckenridge, CO.

HUMAN FACTORS

1. Reiber, T. M., Greenhalgh, P. C., Yates, K. M., Thompson, R. L., Drake, A. M., Newby, N. J., Somers, J. T., Gohmert, D. M., Suhey, J. D., Perry, C. E., Buhrman, J. R., Baldwin, M. A., & Null, C. H. (2013). Comparison of anthropomorphic test device and human volunteer responses in simulated landing impact tests of U.S. space vehicles. 53rd International Conference on Environmental Systems (ICES), Louisville, KY.
2. Dischinger, C. H. and Null, C. H. (2023). The risks and threats to functional vision during EVA at Lunar South Pole. DoD Technical Advisory Group Meeting, MSFC, Huntsville, AL.
3. Holbrook, J. and Null, C. H. (2023) The Unintended Consequence of Focusing on Human Error. Psychonomic Society Annual Meeting, San Francisco, CA
4. Null, C. H. (2024) Taking Measure of Human Systems Integration: A View from NASA. Joint meeting of INCOSE 3rd Human System Integration Conference and 2024 International Ergonomics Association. Jeju, S. Korea
5. Dempsey, D. L., Niemann, C. & Huang, Z. C. (2024, October 8-10). Humans to Mars, but How Many? Using Training Qualifications Modeling to Inform Number of Crew. 13th International Association for the Advancement of Space Safety (IAASS) Conference.

LOADS & DYNAMICS

1. Puryear, J., Joglekar, S., VanZwieten, T., Lyons, T. (2024). Modeling Uprighting of the Orion Crew Module using a Finite Element Method with Wave Coupling and Structural Deformability. AIAA SciTech Forum, Orlando, FL.
2. Johnson, D., Kolaini, A., & Kinney, T. (2024, June 4-6). NASA Loads - Leading Outstanding Aerospace Structural Dynamics Solutions. Spacecraft and Launch Vehicles Dynamic Environments Workshop, The Aerospace Corporation, El Segundo, CA.
3. Squire, M., Majed, A., Henkel, E., Kolaini, A., Johnson, D., & Sills, J. (2024, June 4-6). Contact Dynamics Predictions Utilizing a Parameterless Contact Model. Spacecraft and Launch Vehicle (SCLV) Dynamic Environments Workshop, The Aerospace Corporation, El Segundo, CA.
4. Akers, J., Winkel, J., Chin, A., Parks, R., Chandler, D., Stasiunas, E., & Allen, M. (2024, January 29 - February 1). Operational Modal Analysis of the Artemis I Dynamic Rollout Test and Wet Dress Rehearsal. International Modal Analysis Conference (IMAC XLII), Orlando, FL.
5. Hale, M., Davis, J., Barber, W., & Akers, J. (2024, November 3-7). Use of Spectral Analysis of Singular Values as a Test Metric for IMMAT Trials. In Shock and Vibration Exchange (SAVE), Dallas, TX.
6. Sills, J. (2024, June 4-6). The Artemis opportunity: Unraveling multidisciplinary engineering challenges in the exploration age. Keynote Address, 2024 Spacecraft and Launch Vehicle Dynamic Environments Workshop, The Aerospace Corporation, El Segundo, CA.

MATERIALS

1. Park, A., Tilson W., (2024, February 24). NASA's Challenges and Opportunities in Spaceflight Certification of Fracture Critical AM Components. 2024 Worldwide Advanced Manufacturing Symposium (WAMS), Joint NASA/ESA Conference, Orlando, FL. https://ntrs.nasa.gov/citations/20240000849
2. Park, A., Gradl, P. (2024, January). Baking up an Additive Manufacturing Delicacy. 3d Printing Media. AM in Space: Failing Upward.

MECHANICAL SYSTEMS

1. Bergandy, K., Hakun, C., Schepis, J., Matson, M., Martin, E., & Meloy, R. (2023). Lessons Learned from Evaluation and Mitigation of Space Charging Threat Due to Use of Isolated (Hybrid) Bearings on the PACE Ocean Color Instrument. 20th European Space Mechanisms and Tribology Symposium (ESMATS), Warsaw, Poland. https://www.esmats.eu/esmatspapers/pastpapers/pdfs/2023/bergandy.pdf

PROPULSION

1. Jones, J. E. (2024, May 6-9). Lighting Up the Right Brain: Flying Safely and Shaping the Future. Keynote Address, JANNAF Interagency Propulsion Committee Meeting, Oklahoma City, OK.

SENSORS AND INSTRUMENTATION

1. Biagi, C. J., Gibson, T. L., Youngquist, R. C., Nurge, M. A., & Singh, U. N. (2024). Urine Pretreat Concentration Sensor Based on Optical Absorption. Journal of Spacecraft and Rockets, 61(4), 1059-1065. https://doi.org/10.2514/1.A35891

2. Singh, U. N., Kitching, J., Kumar, P., & Gaskin, J. (2024, January 31). NASA and External Quantum Sensing Capability Assessment for NASA Space-based Science Measurements. SPIE Photonics West, San Francisco, CA.
3. Singh, U. N., & Refaat, T. F. (2024, July 7-12). Profiling of Mars Atmospheric Carbon Dioxide Isotopologues using 2-micron Orbiting LIDAR. International Geoscience and Remote Sensing Symposium, Athens, Greece.
4. Youngquist, R. C., Biagi, C. J., Gibson, T. L., Nurge, M., & Singh, U. N. (2024). Optical Wastewater Pretreat Sensor. US Patent Application No. 18,679,648. Filed on May 31, 2024.
5. Refaat, T. F., Petros, M., & Singh, U. N. (2024). Dynamic, Thermally Adaptive Cuboid Crystal Mount for End-pumped Conductively Cooled Solid State Laser Applications. US Patent No. US 12,040,586 B2. Patent awarded on July 16, 2024.

SOFTWARE

1. Prokop, L.E. (2024, March 2-9). Historical Aerospace Software Errors Categorized to Influence Fault Tolerance. Proceedings of the 45th International IEEE Aerospace Conference, Big Sky, MT.
2. Prokop, L.E. (2024). Software Error Incident Categorizations in Aerospace. Journal of Aerospace Information Systems, JAIS, Vol. 21, No. 10 (2024), pp. 775-789 doi: doi/abs/10.2514/1.I011240.

SPACE ENVIRONMENTS

1. Mertens, C. J., Gronoff, G. P., Zheng, Y., Petrenko, M., Phoenix, D., Buhler, J., Willis, E., Jun, I., & Minow, J. (2023, October 9-13). NAIRAS Atmospheric and Space Radiation Environment Model. Applied Space Environments Conference, Huntsville, AL.
2. Minow, J. I., Meloy, R., Parker, L. N., & Collado-Vega, Y. (2023. October 9-13). Space Weather Launch Constraints for JWST. In Applied Space Environments Conference, Huntsville, AL.
3. Mertens, C. J., Gronoff, G., Zheng, Y., Buhler, J., Willis, E. M., Petrenko, M., Phoenix, D., Jun, I., & Minow, J. (2023, November 7-9). NAIRAS Ionizing Radiation Environment Model. In Space Environment Applications Systems and Operations for National Security (SEASONS), The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD.
4. Gronoff, G., Mertens, C. J., Phoenix, D., Tobiska, K., Zheng, Y., Jun, I., & Minow, J. (2023, December 11-15). Comparison of the Nowcast of Aerospace Ionizing Radiation System (NAIRAS) with ISS Measurements. Abstract SH21E-2931, American Geophysical Union Fall Meeting, San Francisco, CA.
5. Minow, J. I., Diekmann, A. M., Willis, E. M., & Coffey, V. N. (2023, December 11-15). L2 Charged Particle Environment Model of the Earth's Distant Magnetotail. In Abstract SM43B-3094, American Geophysical Union Fall Meeting, San Francisco, CA.
6. Campola, M. (2024, January 29 - February 2). Electro Magnetic Applications (EMA) Expo 2024: A Practical Approach to Space Environmental Effects, Day 1 High Energy Effects. EMA Expo, Golden, CO. (invited)
7. Campola, M. (2024, January 29 - February 2). Electro Magnetic Applications (EMA) Expo 2024: A Practical Approach to Space Environmental Effects, Day 2 effects in-orbit. EMA Expo, Golden, CO. (invited)
8. Mertens, C. J., Gronoff, G. P., Phoenix, D., Zheng, Y., Jun, I., Minow, J., & Nunez, M. (2024, January 28 - February 1). Advances in NAIRAS Atmospheric and Space Radiation Nowcast and Forecast. American Meteorological Society 104th Annual Meeting, 21st Conference on Space Weather, Baltimore, MD.
9. Gronoff, G., Mertens, C. J., Phoenix, D., Tobiska, K., Zheng, Y., Jun, I., & Minow, J. (2024, January 28 - February 1). The Effect of an SEP Event on Astronauts Doing a Spacewalk as Computed by the Nowcast of Aerospace Ionizing Radiation System (NAIRAS). American Meteorological Society 104th Annual Meeting, 21st Conference on Space Weather, Baltimore, MD.
10. Minow, J. I. (2024, March 27). SCAF 2024: Welcome and NASA Introductory Comments. Spacecraft Anomalies and Failures Workshop, GSFC, Greenbelt, MD.
11. Minow, J. (2024, April 15 - 19). Space Weather Support for the James Webb Space Telescope Launch. NOAA Space Weather Workshop, Boulder, CO. (invited)
12. Mertens, C. (2024, April 15 - 19). Nowcast of Aerospace Ionizing Radiation System (NAIRAS) Model. NOAA Space Weather Workshop, Boulder, CO. (invited)
13. Alden, C. (2024, April 15-19). Space Weather Support for Human Exploration: NASA Moon-to-Mars (M2M). NOAA Space Weather Workshop, Boulder, CO. (invited)
14. Minow, J. I., & Manning, M. (2024, April 19). SCAF 2024: Outbrief to NASA NRO Working Group. NASA/NRO Working Group, virtual. (invited)
15. Minow, J. (2024, April 29-30). NESC Space Environments Technical Discipline Team Activities. 13th NASA Space Exploration & Space Weather Workshop, GSFC, Greenbelt, MD. (invited)
16. Mertens, C. J. (2024, June 3-7). NAIRAS Version 3: Ionizing Radiation Predictions from Ground to Space. Community Coordinated Modeling Center Workshop, College Park, MD.
17. Minow, J. I., Parker, L. N., Meloy, R., Zheng, Y., & Buhler, J. (2024, June 17-21). Development and Use of Spacecraft Charging Flight Constraints. 17th Spacecraft Charging Technology Conference, Avignon, France.
18. Parker, L. N., Jun, I., Kim, W., Green, N., Anderson, A., Mandell, M., Davis, V., Likar, J., Hoffman, R., Cooke, D., Gibson, Z., Shah, J., Minow, J., & Wang, J. (2024, June 17-21). United States Spacecraft Charging Overview. 17th Spacecraft Charging Technology Conference, Avignon, France.
19. Minow, J. I. (2024, July 13-21). Radiation Environments for Low Earth Orbit Space Stations. COSPAR 2024, 45th Scientific Assembly, Busan, Korea.
20. Minow, J. I., Jordanova, V. K., Pitchford, D., Ganushkina, N. Y., Zheng, Y., Delzanno, G. L., Jun, I., & Kim, W. (2024, July 13-21). Recommendations from the ISWAT G3 Surface Charging Paper. COSPAR 2024, 45th Scientific Assembly, Busan, Korea.
21. DeStefano, A. (2024, July 13-21). Artemis Radiation Environment. COSPAR 2024, 45th Scientific Assembly, Busan, Korea.
22. Kim, W., Minow, J., Andersen, A., Meloy, R., & Ratliff, J. (2024, July 13-21). Statistical Analysis of Long-Term Averaged Solar Wind as the Internal Charging Environment. COSPAR 2024, 45th Scientific Assembly, Busan, Korea.
23. Corti, C., Whitman, K., Slaba, T., Minow, J., & Jun, I. (2024, July 13-21). Extension of the NASA Badhwar-O'Neill Model's Predictive Capabilities Beyond 1 AU. COSPAR 2024, 45th Scientific Assembly, Busan, Korea.
24. Dawkins, E. C. M., Stober, G., Carrillo-Sánchez, J. D., Janches, D., Weryk, R., Hormaechea, J. L., Bruzzone, J. S., & Plane, J. M. C. (2023). A Novel Methodology to Estimate Pre-atmospheric Dynamical Conditions of Small Meteoroids. Planetary and Space Science, 238, 105796. https://doi.org/10.1016/j.pss.2023.105796
25. Mertens, C. J., Gronoff, G. P., Zheng, Y., Buhler, J., Willis, E., Petrenko, M., Phoenix, D., Jun, I., & Minow, J. (2024). NAIRAS Atmospheric and Space Radiation Environment Model. IEEE Transactions on Nuclear Science, 71(4), 618-625. https://doi.org/10.1109/TNS.2023.3330675
26. Janches, D., Bruzzone, J. S., Dawkins, E. C. M., Weryk, R., Carrillo Sanchez, J. D., Egal, A., Stober, G., Hormaechea, J. L., Vida, D., & Brunini, C. (2023). Radar Observation of the New λ-Sculptorid Meteor Shower. Astronomy and Astrophysics, 687. https://doi.org/10.1051/0004-6361/202450281
27. Phoenix, D. B., Mertens, C. J., Gronoff, G. P., & Tobiska, K. (2024). Characterization of Radiation Exposure at Aviation Flight Altitudes Using the Nowcast of Aerospace Ionizing Radiation System (NAIRAS). Space Weather, 22, e2024SW003869. https://doi.org/10.1029/2024SW003869
28. Minow, J. I., Jordanova, V. K., Pitchford, D., Ganushkina, N. Y., Zheng, Y., Delzanno, G. L., Jun, I., & Kim, W. (2024). ISWAT Spacecraft Surface Charging Review. Advances in Space Research. https://doi.org/10.1016/j.asr.2024.08.058
29. Janches, D. (2024, September 16-20). Meteor astronomy: Results from the First 15 years of Observations. Annual Meeting of the Argentine Astronomy Association, La Plata, Argentina. (invited)
30. Schonberg, W., Squire, M. (2024). Development of Ballistic Limit Equations in Support of the Mars Sample Return Mission. Journal of Space Safety Engineering, June 15.
31. Schonberg, W.; Squire, M. (2024, September 8-13.). Extending the Applicability of TPS Ballistic Limit Equations Beyond the Testable Regime. Hypervelocity Impact Symposium, Tsukuba, Japan.
32. Corbett, B; Williamsen, J.; Stellingwerf, R.; Squire, M. (2024, September 8-13). Smooth Particle Hydrodynamic Code Predictions for Meteoroid Damage in Thermal Protection Systems Shielded by Composite Structures. Hypervelocity Impact Symposium, Tsukuba, Japan.
33. Squire, M.; Sarli, B.; Schonberg, W.; Williamsen, J.; Parker, P.; Christiansen, E.; Jenkin, A.; Steward, K.; Peterson, G.; McKown, Q.; Tulaba, B.; Hoffman, K. (2024, September 8-13). Mars Sample Return Earth Entry System MMOD Risk Uncertainty Analysis. Hypervelocity Impact Symposium, Tsukuba, Japan.

STRUCTURES:

1. Rudd, M.T., Schultz, M.R., Gardner, N.W., Kosztowny, C.J.R., and Bisagni, C. (2024). Experimental validation of the buckling behavior of unreinforced and reinforced composite conical-cylindrical shells for launch-vehicles. In Composite Structures, 349-350. https://doi.org/10.1016/j.compstruct.2024.118493.

2. Rudd, M.T., Schultz, M.R., Gardner, N.W., Kosztowny, C.J.R., and Bisagni, C. (2024). Analysis and Testing of a Launch-Vehicle-Like Composite Conical-Cylindrical Shell. In AIAA Journal, 62(9), 3526-3543. https://doi.org/10.2514/1.J063617.
3. Rudd, M.T., Schultz, M.R., and Bisagni, C. (2024). Buckling Behavior of Conical-Cylindrical Shells and Design Considerations for Launch-Vehicle Applications. Proceedings of the AIAA SciTech 2024 Forum, Orlando, FL. https://doi.org/10.2514/6.2024-0034.
4. Pourkamali-Anaraki, F., Husseini, J. F., Pineda, E. J., Bednarcyk, B. A., & Stapleton, S. E. (2023). Two-stage modeling for data-driven design optimization with application to composite microstructure generation. International Scientific Journal Engineering Applications of Artificial Intelligence, In press.
5. Kaleel, I., Pineda, E. J., & Bednarcyk, B. A. (2024). Micromechanical modeling of discontinuous long fiber reinforced composites, Mechanics of Advanced Materials and Structures, 1–9. DOI: 10.1080/15376494.2024.2352798.
6. Saseendran, V., Yamamoto, N., Kaleel, I., Pineda, E. J., Bednarcyk, B. A., Collins, P., & Radlińska, A. (2024, January 8-12). Multiscale modeling of reconstructed tricalcium silicate using NASA Multiscale Analysis Tool. 2024 AIAA SciTech Forum, Orlando, FL.
7. Arnold, S. M., Ricks, T. M., Pineda, E. J., & Bednarcyk, B. A. (2024, January 8-12). An enabling platform for achieving multiscale multiphysics analysis of multiphase materials. 2024 AIAA SciTech Forum, (Invited NASA 2040 Vision Session), Orlando, FL.
8. Pineda, E. J., Ricks, T. M., Bednarcyk, B. A., & Arnold, S. M. (2024 January 8-12). NASA Multiscale Analysis Tool (NASMAT) for ICME ecosystem. 2024 AIAA SciTech Forum (Invited NASA 2040 Vision Session), Orlando, FL.
9. Stapleton, S. E., Carey, E. J., Husseini, J. F., Barlow, G. J., Ghaffari, S. H., Pourkamali-Anaraki, F., Furey, C. J., Pineda, E. J., & Bednarcyk, B. A. (2024, January 8-12). Modeling the stochastic response of fiber reinforced composites with varied representative volume element sizes. 2024 AIAA SciTech Forum (Invited NASA 2040 Vision Session), Orlando, FL.
10. Bednarcyk, B. A., Mulhearn, W. D., Kaleel, I., Pineda, E. J., & Steele, P. E. (2024, April 29-May 1). Multiscale Modeling of Short Fiber Additively Manufactured Composites, ASME Structures, Structural Dynamics, and Materials Conference (SSDM 2024), Renton, WA.
11. Desai, I., Kaleel, I., Pineda, E. J., Ricks, T. M., Gustafson, P. A., Bednarcyk, B. A., Arnold, S. M., Waas, A. M., & Uekermann, B. (2024, April 29-May 1). A macro solver agnostic software framework for massively multiscale modeling using NASA multiscale analysis tool and PreCICE, ASME Structures, Structural Dynamics, and Materials Conference (SSDM 2024), Renton, WA.
12. Jois, K.C., Welsh, M.R., Bednarcyk, B.A., & Pineda, E.J. (2024, October 21-23). Statistical Multiscale Progressive Failure Analysis of Unbalanced Plain Weave Composites. American Society for Composites 39th Technical Conference, San Diego, CA.
13. Ricks, T.M., Bednarcyk, B.A., Mital, S.K., Izquierdo, S.F., & Abbott, L.J. (2024, October21-23). Multiscale and Multifidelity Modeling of a 3D Woven Composite Thermal Protection System, American Society for Composites 39th Technical Conference, San Diego, CA.
14. Bukenya, K., Olaya, M., Bednarcyk, B.A., Pineda, E.J., & Maiarù, M. (2024 October 21-23). Hierarchical multiscale process modeling of a textile composite Y-joint for the Aurora D8 aircraft, American Society for Composites 39th Technical Conference, San Diego, CA.
15. Brust, F. W., Punch, E., Twombly, E. (2024) Full Scale Three-Dimensional Moving Arc Weld Analysis of Control Rod Drive Mechanism J-groove Welds and Implications on Cracking", paper PVP2024-125081, Proceedings of the ASME 2024 PVP Conference, Bellevue, WA.
16. Brust, F. W. (2024). Residual Stresses in Layered Pressure Vessle Nozzles, paper PVP2024-125218, Proceedings of the ASME 2024 PVP Conference, Bellevue, WA.
17. Anto, A.D., Fleishel, R., TerMaath, S., and Abedi, R. (2024) Size Dependency of Elastic and Plastic Properties of Metallic Polycrystals Using Statistical Volume Elements. Applied Sciences, 14(18), https://doi.org/10.3390/app14188207.
18. Bhattacharya, M., Crusenberry, C., Smith, K., and TerMaath, S. (2024, January 8-12) Surface roughness effects on the fracture behavior of adhesively bonded joints, AIAA SciTech, Orlando, FL.
19. TerMaath, S., Handy, A., Crusenberry, C., Ytuarte, E., and Kinan, B. (2024, September 3-6) Non-Deterministic Investigation of Composite Microstructure Effects on Macroscale Properties. 27th International Conference on Composite Structures (ICCS27), Ravenna, Italy.
20. TerMaath, S., Bezem, K., Handy, A. and Crusenberry, C. (2024, September 11-13) Investigation of installation effects on the fracture behavior of adhesively bonded joints. EMI 2024 International Conference, Vienna, Austria.
21. Das Anto, A., Fleishel, R., TerMaath, S., and Abedi, R. (2024, November 17-21) Comparison of Volume Element Sizes for Elastic and Plastic Properties in Polycrystalline Steels. ASME International Mechanical Engineering Congress and Exposition (IMECE2024), Portland, OR.
22. Handy, A., Daffron, M., Vaidya, U., and TerMaath, S. (2024, June 24-27) Effects of Constituent Materials and Processing on Microstructural Defects and Shear Strength of C/C Composites. NSMMS & CRASTE Joint Symposia, Madison, WI.
23. Good, B., Handy, A., and TerMaath, S. (2024, June 11-14) Experimental and Computational Modeling of Brain Shunt Performance. SB3C, Lake Geneva, WI.
24. TerMaath, S., Handy, A., Crusenberry, C., and Ytuarte, E. (2024, April 23-25) Investigation of Processing Effects on Macroscale Properties. Quarter Century of Peridynamics, Tuscon, AZ.

SYSTEMS ENGINEERING

1. Huang, Z. (2024). Validation and Adjustment of Prior Distributions to Improve Bayesian Analysis for Beta-Binomial Data. In RAMS 2024.

THERMAL CONTROL AND PROTECTION

1. Rickman, S.L. (2023, November). Development and Application of a Novel Calorimetry Technique for the Study of Lithium-Ion Cell Thermal Runaway. Invited talk to Qinetiq.
2. Rickman, S.L. (2024, June and August). Introduction to Orbits. Rice Envision Aerospace Academy, Houston, TX.
3. Rickman, S.L. (2024, August). Introduction to Numerical Methods in Heat Transfer. Thermal and Fluids Analysis Workshop (TFAWS), Cleveland, OH.

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

1. NASA/TM-2024000713 Composite Overwrapped Pressure Vessels (COPV) Stress Rupture Reliability, NESC Statistical Analysis of NESC and International Space Station Program (ISSP) Testing and a Proposed Phenomenological Model (PM)
2. NASA/TM-20230014536 Assessment of Electrical, Electronic, and Electromechanical (EEE) Parts Copper Wire Bonds for Space Programs
3. NASA/TM-20230014779 Passivation of Spacecraft Pressure Vessels: Some Comments on Requirements, Principles, and Practices
4. NASA/TM-20240009657 Characterization of Internal Insulation Thermal Performance
5. NASA/TM-20240011265 Trade Space Analyses: Balancing Crew and Mission Design Parameters
6. NASA/TM-20240002004 Agency Additive Manufacturing (AM) Certification Support Team (AACT) Risk Reduction – Safe Life Category: Fracture Control Framework for Un-inspectable Fracture Critical AM Parts
7. NASA/TM-20230018123 Independent Panel Report for Technical Assessment of NASA and External Quantum Sensing Capabilities
8. NASA/CP-20240004533 Proceedings of the Quantum Sensing Workshop, September 2022
9. NASA/TM-20230014984 Examination of Space Vehicle Ethernet Interconnects
10. NASA/TM-20230018439 Short-Transverse Tensile Fracture Behavior of Thick AA2219 Plate - Effects of q (Al2Cu) Particle Size and Distribution
11. NASA/TM-20240007117 NASA Space Observatory Precision Pointing Benchmark Problem Development
12. NASA/TM-20230015574 Mars Sample Return (MSR) Orbiting Sample (OS) Model Review Phase II: Contact Modeling
13. NASA/TM-20240010785 NASA Agile Community of Practice
14. NASA/TM-20240007062 Helium Conservation by Diffusion Limited Purging of Liquid Hydrogen Tanks
15. NASA/TM-20240007112 Mars Sample Return (MSR) Capture, Containment, and Return (CCRS) Orbiting Sample Model Review Phase III
16. NASA/TM-20240009366 Failure-Tolerant Avionics for Crewed Space Systems Recommended Best Practices
17. NASA/TP-20240009981 Best Practices and Considerations for Using Autonomous Flight Termination Software In Crewed Launch Vehicles
18. NASA/TM-20240004143 Out of Plane Stresses Using a Beam-Based Elastic Foundation Bonded Joint Model.
19. NASA/TM-20240013073 Filament Wound Composite Analysis Using NASA's Multiscale Analysis Tool (NASMAT) and Finite Element Analysis
20. NASA/TM−20210024081 Test and Analysis of the 8-foot Diameter Cylindrical Sandwich Composite Test Article CTA8.2B

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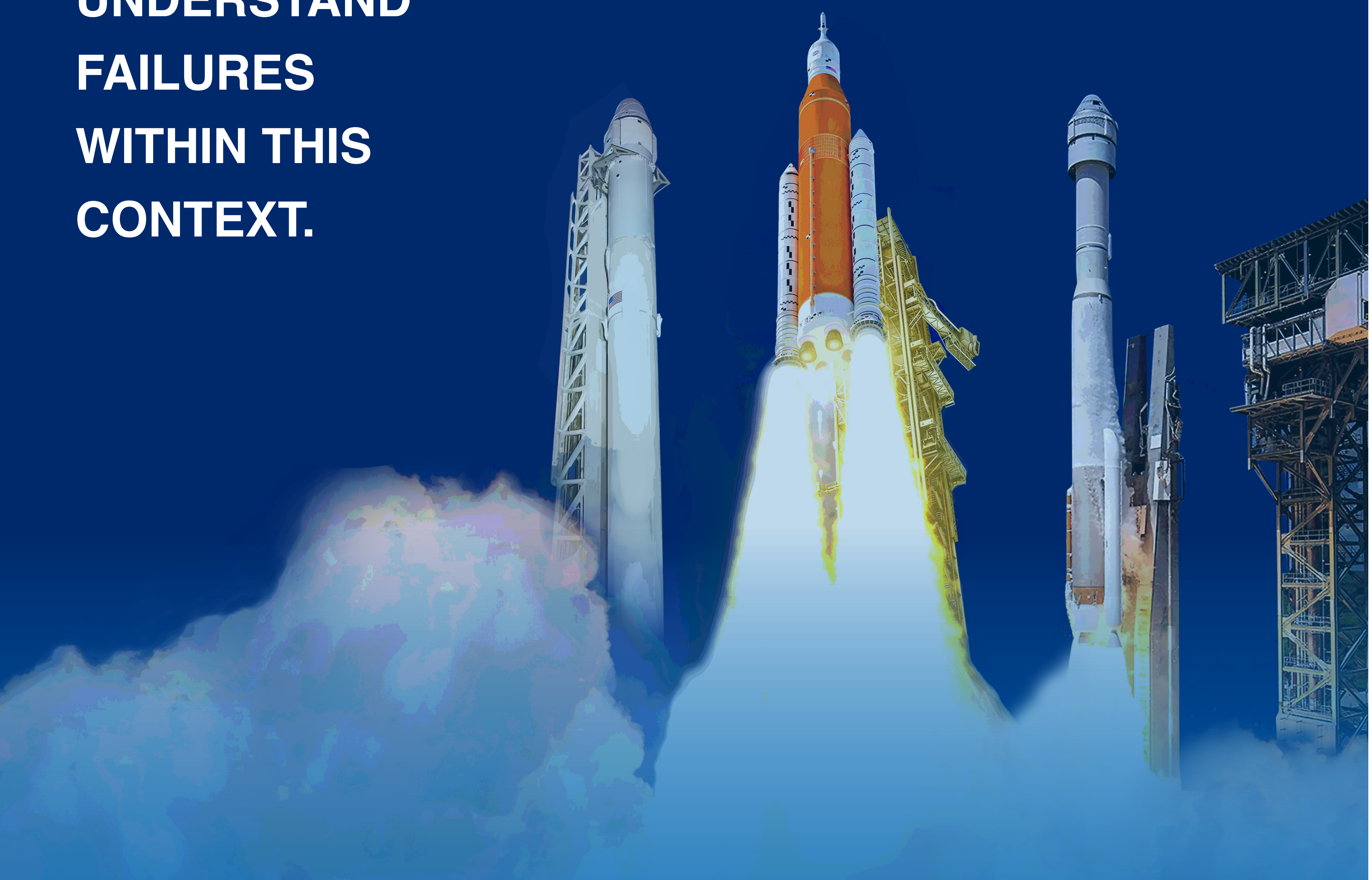

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