National Aeronautics and
Space Administration

2019

NASA Engineering & Safety Center

NESC

TECHNICAL UPDATE

www.nasa.gov

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- Mary Beth Wusk

Marshall Space Flight Center
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Stennis Space Center
- Michael D. Smiles

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For general questions and requests for technical assistance, visit

NESC.NASA.GOV

To submit a technical request anonymously, mail it to:
NESC
NASA Langley Research Center
Mail Stop 118
Hampton, VA 23681

From NASA Leadership

Stephen Jurczyk
NASA Associate Administrator

"When Artemis astronauts return to the Moon in 2024, it will be the culmination of several major development programs at NASA and the beginning of a new era in space exploration.

The Orion Multi-Purpose Crew Vehicle and Space Launch System are reaching final assembly and test milestones, and their launch will set the stage for America's sustained lunar presence. Test flights have begun for spacecraft under development with the Commercial Crew Program, and soon we will be launching astronauts from U.S. soil again. The James Webb Space Telescope, expected to launch in 2021, will give us a brand new perspective on science by providing our most in-depth view of the universe and its origins. Throughout the design and development of these programs, NASA has relied on the NESC for solutions to the critical engineering challenges we have faced along the way. As we move forward in developing new space capabilities such as the Gateway and Human Landing System, the NESC will continue its integral role in ensuring the safety of our flight crews and advancing the development of engineering and technology that will prepare us for long-term presence in space."

Ralph R. Roe, Jr.
NASA Chief Engineer

"The NESC continues to focus on the critical steps necessary to enable mission success in all of NASA's major programs and projects.

In 2019, the NESC remained committed to supporting NASA's missions as well as the commercial partners' endeavors to transport astronauts to the International Space Station. At the same time, a new initiative was developed with the Artemis Program in advancing NASA's human spaceflight capability to get astronauts to the surface of the Moon. With each program in development comes the need for in-depth technical expertise and rigor in developing and certifying vehicles for flight. The NESC is the go-to organization for this much needed expertise, making significant contributions to enabling safe, reliable systems for exploration. With over 900 independent technical assessments and supporting activities with in-line work, the NESC is at the forefront of enabling technical solutions to NASA's most critical and demanding challenges, on Earth, to the Moon, and beyond."

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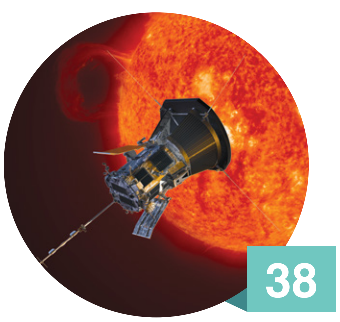
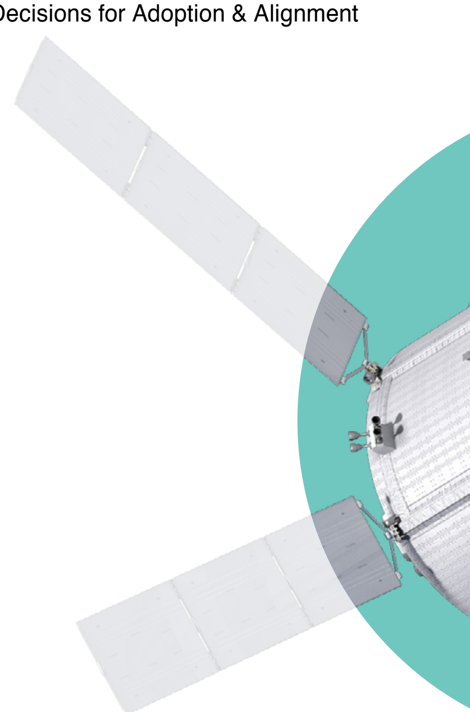




NASA Engineering & Safety Center

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 distinctively unbiased technical assessments to enable more informed decisions.

Engineering Excellence

The NESC draws on the knowledge base of technical experts from across 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.

Independence & Objectivity

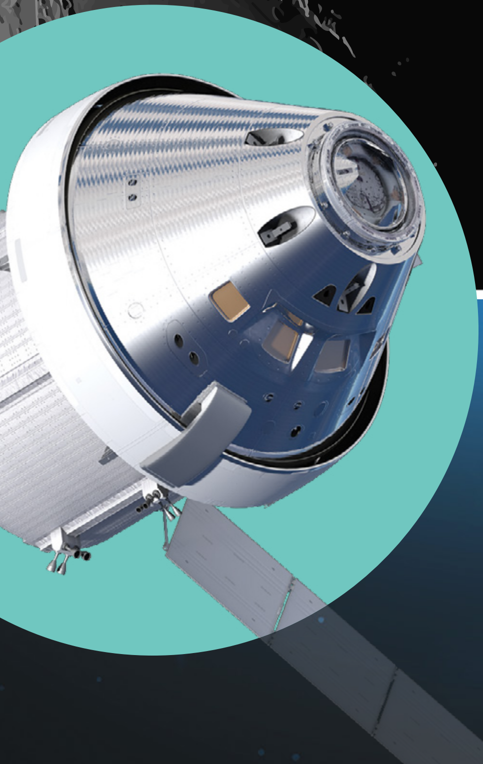
The NESC performs technical assessments and provides recommendations based on independent testing and analysis rather than subjective opinion. An independent reporting path and independent funding from the Office of the Chief Engineer help ensure objective technical results for NASA.

The NESC Insignia Origin

"I named my spacecraft Sigma Seven. 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

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

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



NESC Mission

To perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success. The NESC engages proactively to help NASA avoid future problems.

The NESC in 2019

Timmy R. Wilson
NESC Director

NASA's legacy includes the names Apollo, Hubble, Viking, Voyager, and the Space Shuttle. These historic Programs succeeded by looking ahead: beyond what was possible at the time and exceeding expectations. That philosophy is unchanged.

NASA's vision for the future is returning humans to the Moon and then taking them to Mars, sending astronauts to the International Space Station on American commercial spacecraft, exploring the solar system, and observing the galaxy and the universe beyond.

The NASA Engineering and Safety Center (NESC) contributes to this forward momentum. And while this year's Technical Update highlights what the NESC has achieved this past year, it does so in the context of how the NESC is helping to achieve the Agency's goals for the future. Over half of the activities that the NESC is involved with are projects still in the design phase.

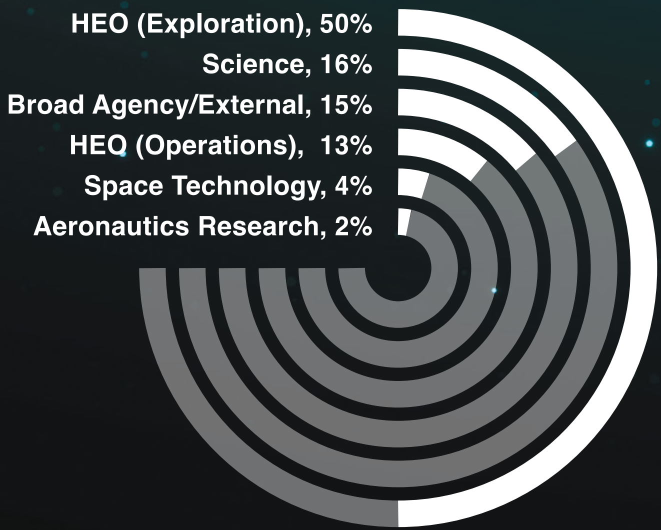
The NESC's charge is to ensure safety and mission success for NASA's high-risk endeavors through engineering excellence by deploying assessment teams. Each assessment team is constructed to address a specific technical issue and comprises people with the technical expertise needed for that particular problem. Assessment team members are pulled from technical discipline teams (TDT)—ready teams of experts in 20 different engineering disciplines. TDT members come from all across NASA, academia, industry, and other government agencies.

The offices within the NESC work together to form assessment teams quickly and provide them with the support they need. The NASA Technical Fellows lead the TDTs and are senior NASA engineers and scientists who act as stewards of their disciplines; Principal Engineers lead large, cross-discipline assessment teams; NESC Chief Engineers are liaisons between the NESC and each Center; the Management and Technical Support Office coordinates administrative and budgetary aspects of each assessment; and the NESC Integration Office provides programmatic, organizational, and technical integration for the NESC and assessments.

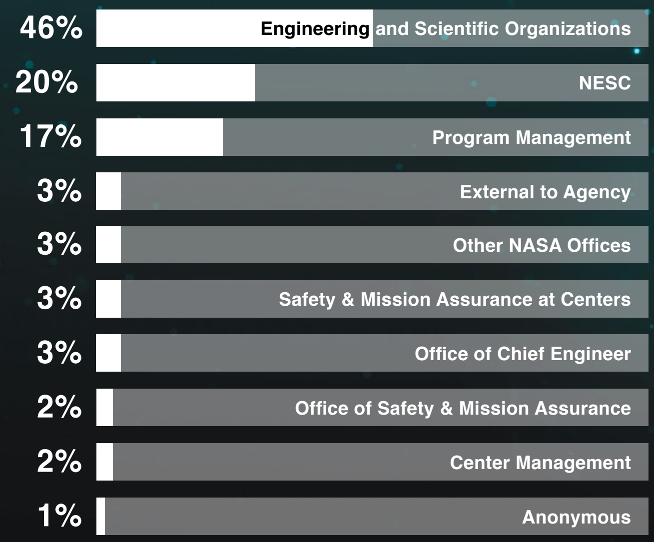
The diverse individuals from these groups combine to form the NESC Review Board (NRB), which must approve the results of every assessment performed by the NESC. The NRB represents a variety of experience bases and technical backgrounds, so the NRB members approach each issue from a different vantage point. The result is a well-rounded understanding of the problems and a robust decision-making process.

The NESC also helps NASA prepare for the future by encouraging younger engineers to participate in NESC assessments. This allows them to gain experience at the side of veteran engineers while building relationships that can be carried with them throughout their careers.

The NESC is a resource for all of NASA, providing independent technical assistance for the programs that will make history—as well as those continuing programs that already have.

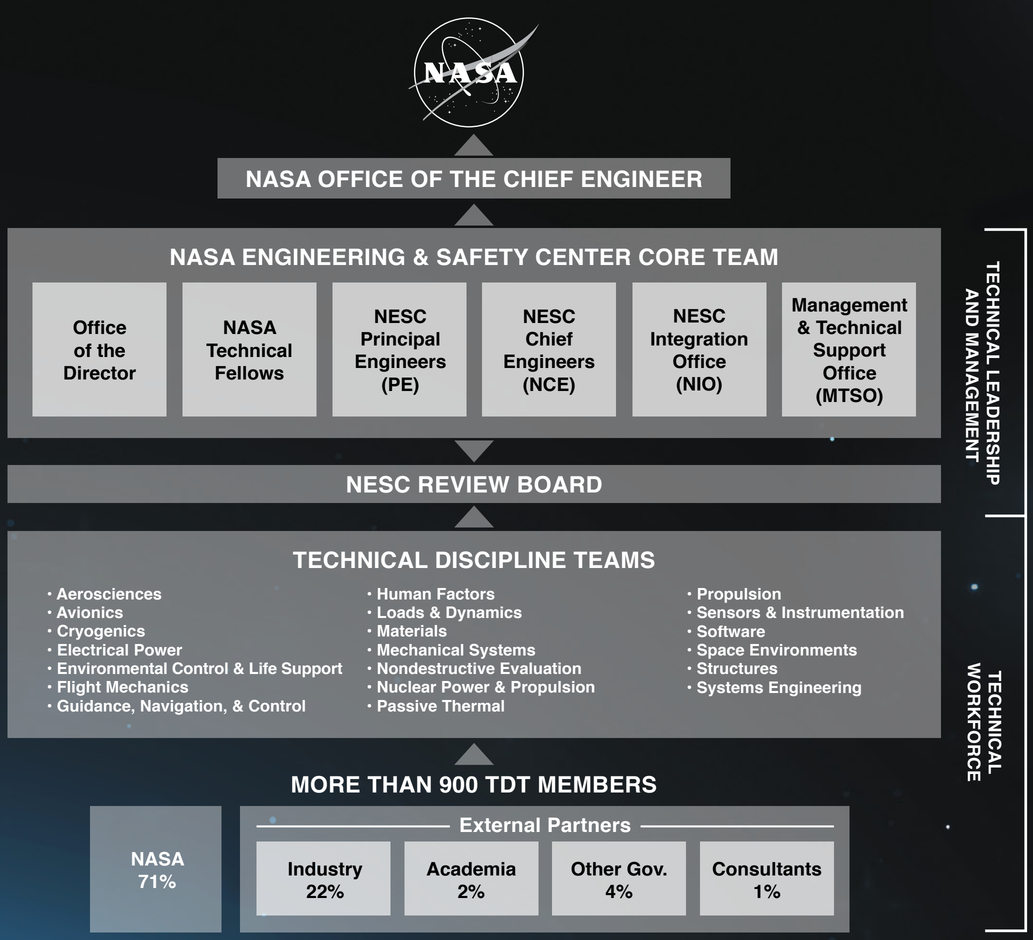


ACCEPTED REQUESTS
BY MISSION DIRECTORATE
FY14-FY19



SOURCES OF
ACCEPTED REQUESTS
SINCE 2003

921 Accepted Requests Since 2003, 64 in FY19

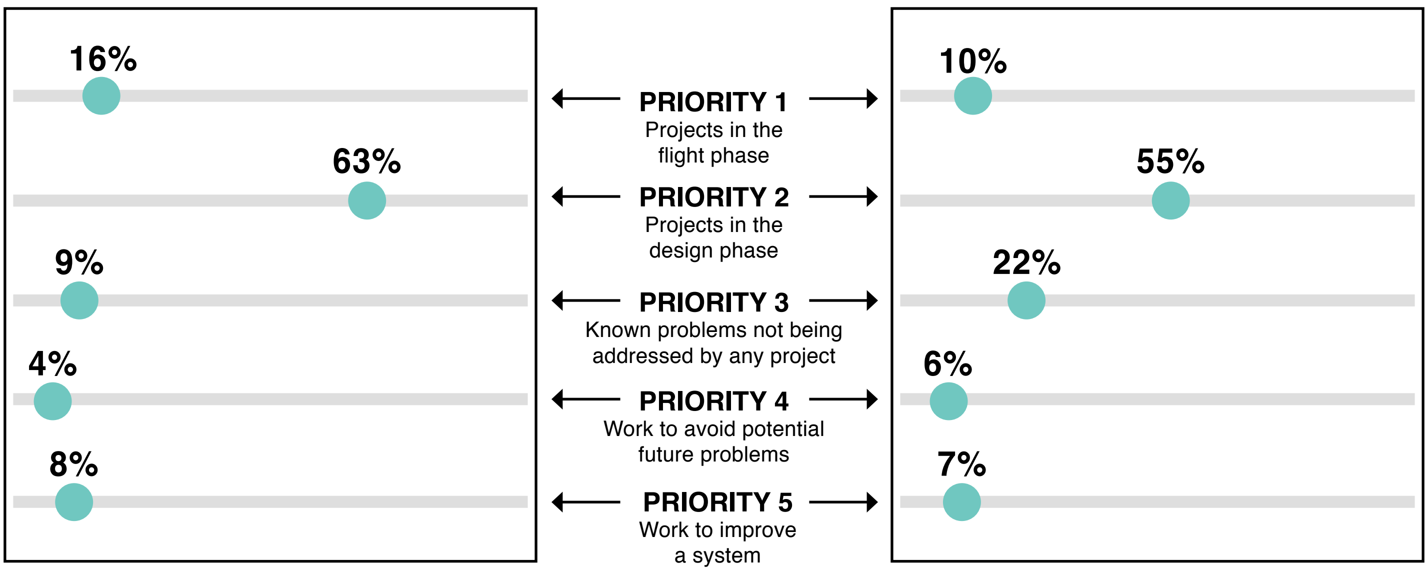


Members of the NESC
October 2019

Data as of September 30, 2019

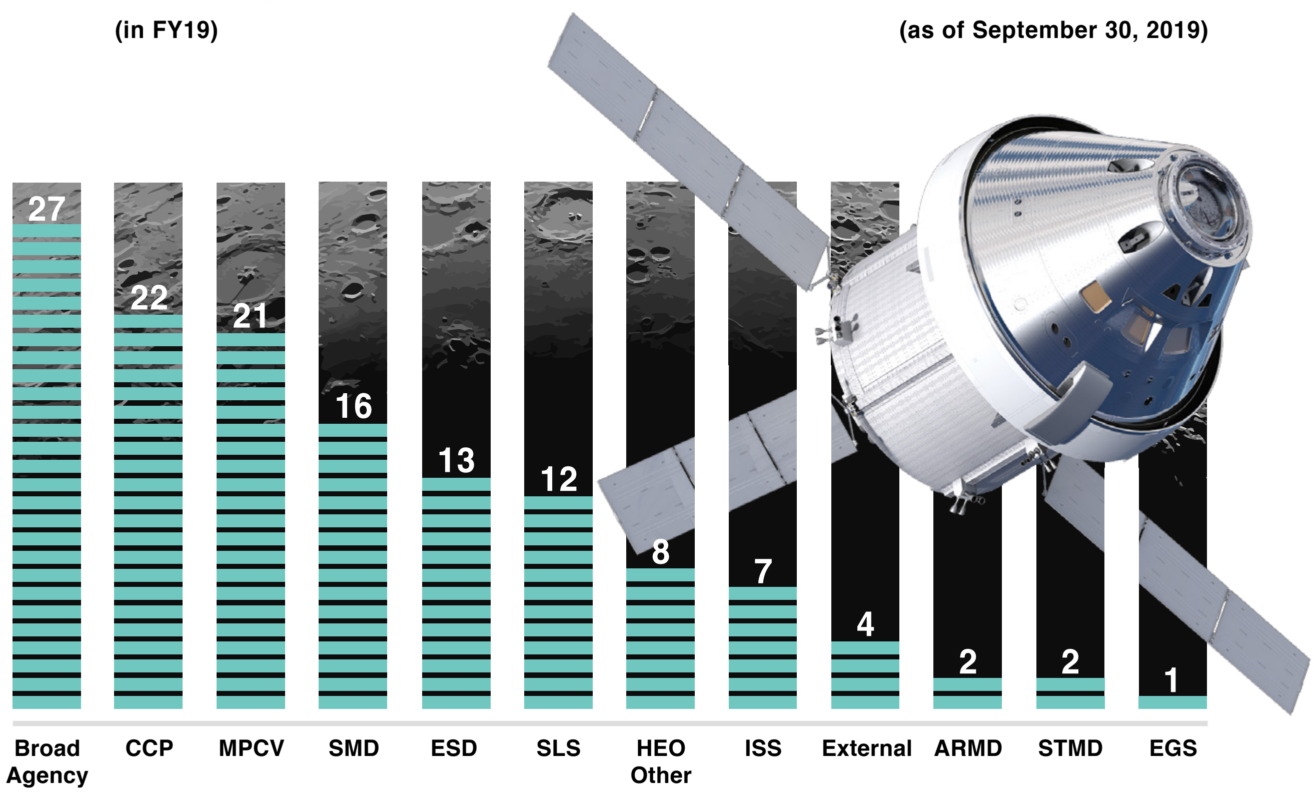
Assessments & Support Activities

Assessments typically include independent testing and/or analyses, the results of which are peer reviewed by the NESC Review Board and documented in engineering reports. Support activities typically include providing technical expertise for consulting on program/project issues, supporting design reviews, and other short-term technical activities.



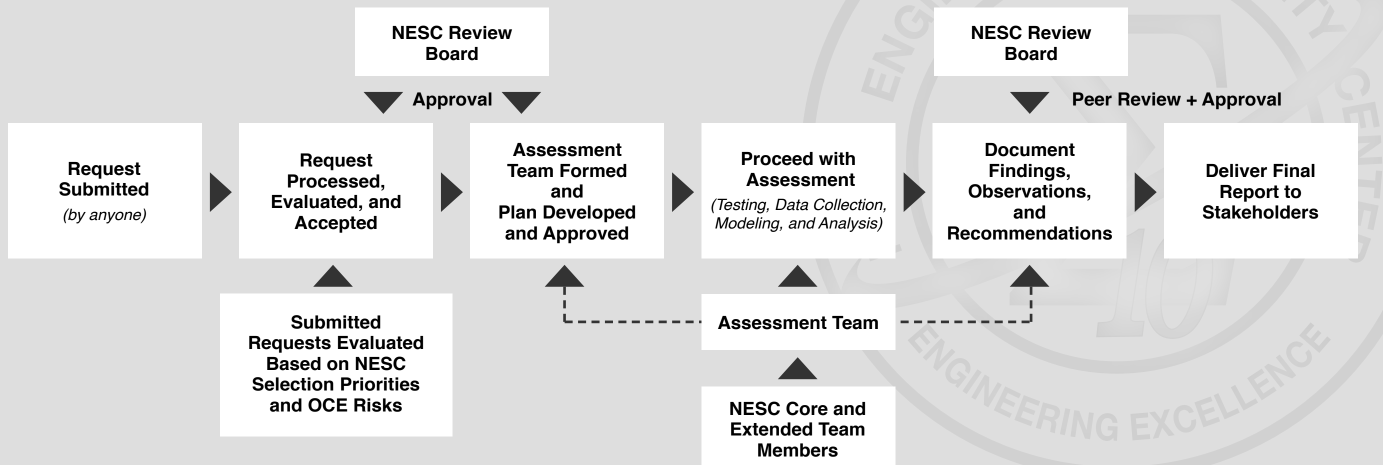
68 COMPLETED REQUESTS
(in FY19)

135 IN-PROGRESS REQUESTS
(as of September 30, 2019)



135 IN-PROGRESS REQUESTS
(as of September 30, 2019)

NESC Assessment Process:



The NESC assessment process is key to developing peer-reviewed engineering reports for stakeholders. Requests for 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 original request. An NESC team's findings, observations, and recommendations are rigorously documented within an engineering report and are peer reviewed and approved by the NRB prior to release to the stakeholder.

Priority 1

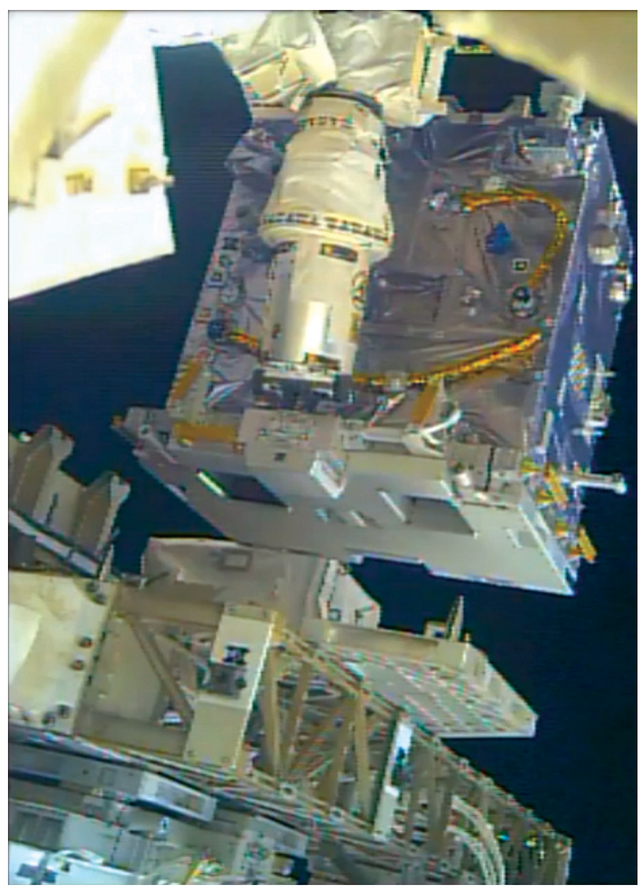
Projects in the Flight Phase

Completed Assessments

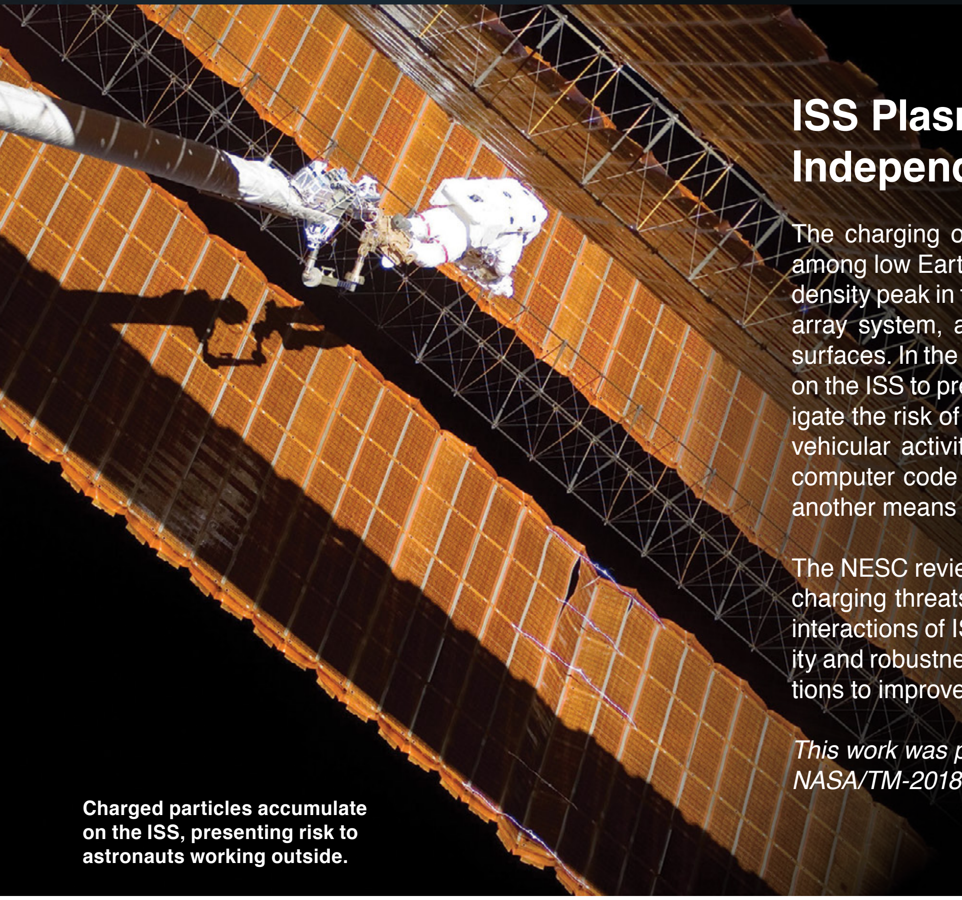
RRM3 Transfer Valve Issue

To extend the life of satellites that provide essential services such as weather monitoring or air traffic management, NASA's Satellite Servicing Projects Division developed the third phase of its Robotic Refueling Mission (RRM3) to demonstrate that satellites, even those not intended to be serviced after launch, could be resupplied with a cryogenic fluid robotically in orbit. During RRM3 ground tests of a simulated liquid methane transfer, cryogenic solenoid-actuated isolation valves experienced an uncommanded closure. The NESC conducted tests using a spare engineering unit to characterize the solenoid valve's open and hold-open behavior and determine the minimum controller settings required to keep the valves open. The assessment also provided enhancements to the simulation model of the cryogen transfer process to better understand heat loads induced into the transfer fluid from the solenoid valves.

This work was performed by ARC, GRC, and GSFC.
NASA/TM-2019-220265



The RRM3 fluid transfer module during installation on the International Space Station External Logistics Carrier.



Charged particles accumulate on the ISS, presenting risk to astronauts working outside.

ISS Plasma Interaction Model Independent Review

The charging of the International Space Station (ISS) is unique among low Earth orbit satellites due to its altitude near the plasma density peak in the ionosphere, the configuration of its photovoltaic array system, and its mixture of nonconducting and conducting surfaces. In the early 2000s, plasma contactor units were deployed on the ISS to prevent accumulation of electrostatic charge and mitigate the risk of electrostatic discharge to astronauts during extravehicular activities. Additionally, plasma interaction model (PIM) computer code was developed to predict ISS charging, useful as another means to mitigate risks to crew when working outside.

The NESC reviewed PIM 3.0 to evaluate its capability of predicting charging threats to crew and assessed algorithms used to model interactions of ISS with the space plasma environment for capability and robustness. The NESC team offered specific recommendations to improve the PIM 3.0 code functionality and usability.

This work was performed by MSFC, JPL, GRC, and JSC.
NASA/TM-2018-220255

Status Update: Pilot Breathing Assessment *(In-Progress)*

In 2017, the Navy requested the NESC provide an independent review of their efforts to address an increased occurrence of physiological episodes (PE) across their F/A-18 fleet. During this work, the NESC identified a deficiency in information about fundamental human breathing patterns during jet aircraft operation critical to confirm or refute potential factors contributing to PEs. The NESC identified that gathering information of this type would be beneficial to the field of aviation and the advancement of human system integration in modern aircraft.

The NESC initiated the Pilot Breathing Assessment (PBA) to better understand human physiology and breathing behaviors in high-performance aircraft during operation. The PBA uses novel instrumentation and advanced analysis to examine pilot physiological state and interaction with aircraft life support systems. NASA test pilots fly instrumented NASA F/A-18 and F-15 aircraft through pre-specified flight profiles while wearing specialized equipment augmented with an advanced sensor system. This sensor system is designed to collect data during flight such as breathing characteristics, gas flow, air composition, and aircraft environment. These data are aligned and examined using advanced analysis techniques to identify pilot/aircraft interactions with potential for negative cognitive and physiological impact.

Kellie Kennedy, LaRC researcher, is fitted with an aviator's helmet and MBU-20/P series oxygen mask with a forehead-mounted physiological monitor prior to hypoxia induction at the Naval Medical Research Unit in Dayton, OH.

The PBA is supporting NASA missions by accurately ascertaining the human physiological and cognitive requirements for operation in adverse environments. This has direct application for NASA vehicles such as the T-38, F-15, X-59, and the ISS. The PBA is providing insight not only with data but also through defining a corpus of processes, procedures, literature, and analysis techniques for consideration in future human/system integration endeavors.

This work is being performed by LaRC, AFRC, ARC, GRC, GSFC, JPL, JSC, WSTF, and also the EPA, UF, USN, and USAF.

Priority 1

In-Progress Assessments

- Orion Super Guppy Loads Issue
- Review of CCP Provider Additive Manufacturing Program
- Review of Orbital Debris Engineering Model ORDEM3.1
- ISS Cargo Tool Loads Analysis Independent Verification and Validation
- CCP Provider Propellant and Pressurization COPV Support
- Pilot Breathing Assessment
- ISS Remote Power Control Module Hot Mate/Demate During Extravehicular Activity
- Validation of ISS Lithium-ion Main Battery's Thermal Runaway Mitigation Analysis and Design Features
- Additional Characterization and Improvements of the Multi-Purpose COPV Liner Inspection System
- Express Logistics Carrier Reverse Capacitor Follow-on Testing
- Recurring Causes of Human Spaceflight Mishaps During Flight Tests and Early Operations

In-Progress Support Activities

- CCP Provider Anomaly
- Rapid Slews for Lunar Reconnaissance Orbiter

Priority 2

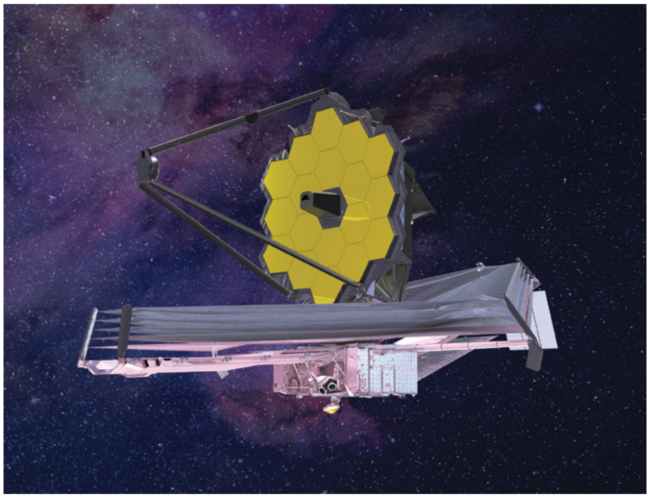
Projects in the Design Phase

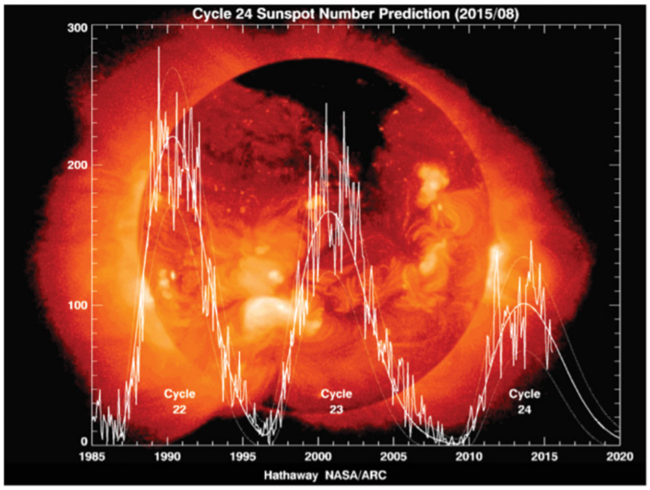
Completed Assessments

JWST Space Environment Launch Constraints

The James Webb Space Telescope (JWST) Project is considering the use of space weather launch constraints to avoid exposing the spacecraft to solar energetic particle radiation and spacecraft charging environments during the first few hours of flight during critical commissioning timeline events, without unduly impacting launch opportunities. An NESC team was requested to perform an independent assessment of a proposed solar proton launch constraint, evaluate the risk for internal charging during the radiation belt transit, and develop a launch constraint to avoid extreme surface charging events when transiting the outer radiation belt and geosynchronous environment. To develop launch constraints, the team used historical space radiation data sets from the Geostationary Operational Environmental Satellite system to examine hypothetical launch attempts and determine the accuracy of a forecast based on a particular launch constraint. Launch constraints for internal charging and surface charging and the resulting launch availabilities were also identified for Project consideration. Internal charging launch constraints were also defined, considering the known hardware capability.

This work was performed by MSFC, KSC, and GSFC.





Top: JWST artist conception. Bottom: Solar activity as measured in sunspot numbers from 1985 to 2020 (years 2016 through 2020 solar predictions) by Dr. David Hathaway, NASA ARC.

Orion Flight Vehicle Simulator Risk Assessment

A foundational step toward the Artemis I mission is the integration of the Orion Multi-Purpose Crew Vehicle (MPCV), Space Launch System (SLS) launch vehicle, and Exploration Ground Systems (EGS). The NESC was initially requested to provide a peer review of the Orion flight vehicle simulator assessment, and at the stakeholder's request, the work evolved to include an independent assessment of how accurate the dynamic math models reflected the computer-aided design models and drawings for the SLS core stage and MPCV. Subsequently, SLS core stage and MPCV coupled loads analysis finite element models were reviewed to identify discrepancies that could affect accuracy of frequency or mode shape predictions. Additionally, the development flight instrumentation proposed for the Artemis I mission was evaluated for its capacity to inform the coupled loads model and meet specific guidance, navigation, & control, as well as loads & dynamics flight test objectives.

This work was performed by JSC and MSFC.

Orion Simulink GNC Code Generation

Simulink is a graphical model-based design tool used to model, simulate, and generate code for control systems. The Orion MPCV Program Guidance, Navigation, & Control (GNC) Team found that compiling and executing the Orion GNC Simulink model was taking nearly a day for every build cycle and hampering code verification cycle time. The NESC was requested to assist the Program in evaluating options for reducing code generation time, including tool updates and model changes that could be incorporated to improve code production. Three parallel investigations were organized. MathWorks, developers of Simulink, used code profiling techniques to analyze the code for potential problems and improvements. Draper Laboratories investigated alternative approaches to reduce the code generation time, and a JSC/Mathworks team investigated upgrading all of the MathWorks tools for speed improvements. The Draper analysis indicated ways to reduce the code build times by approximately 50% if significant model changes and tool upgrades were implemented. This is a potential long-term approach for the Artemis II mission. For the near-term support of the Artemis I mission with minimal impact to schedule, upgrading the MathWorks tools allowed the GNC Team to reduce the model-to-code generation time by half and double the number of verification runs.

This work was performed by LaRC and JSC.

Orion MPCV integration with the European Service Module for the Artemis I mission.

Application of System Identification to Parachute Modeling

A pendulum motion can sometimes develop during descent of the Orion crew module when tested under only two of the three main Capsule Parachute Assembly System (CPAS) parachutes. The NESC investigated the application of modern system identification (SID) techniques for the development of high-fidelity parachute simulation models from parachute drop-test flight data. Used in aircraft modeling and design, a SID model can inform designers of potential paths to correct undesired behavior or flight characteristics.

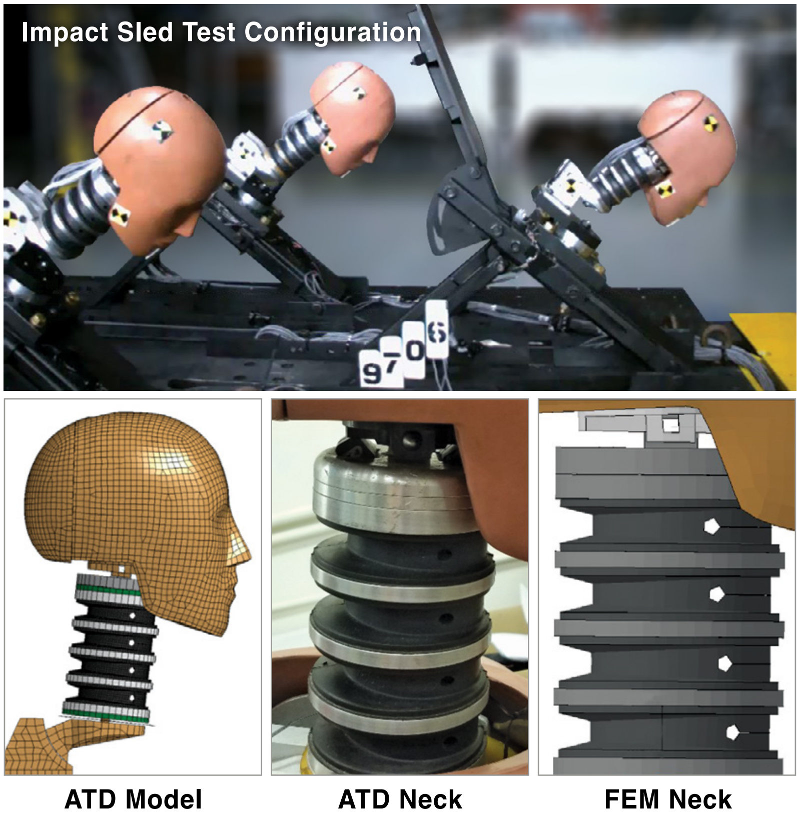
The NESC assessment team developed two independent nonlinear three-body simulations (Capsule Dynamics, and Capsule & 2-Parachutes) as tools that could be easily modified and integrated with other SID tools. One modeling approach, equation error modeling, matches parachute aerodynamic coefficients. This was shown to be successful in that accurate nonlinear aerodynamic force models with good prediction capability were generated by applying equation-error SID flight test data exhibiting pendulum motion. Another SID approach, output error modeling, was investigated but was determined to need further research and development.

This work was performed by LaRC and JSC.
NASA/TM-2019-220410 Vol. 1, NASA/TM-2019-220410 Vol. 2

Drop test using only two of three CPAS main parachutes.

ATD Model Correlation Improvement for Large Male Occupants

Finite element models (FEM) of head and neck anthropomorphic test devices (ATD) are an essential component of the predictive tools used to quantify the risk of injury to crew under dynamic loading conditions. The NESC conducted tests to validate FEMs of 5th, 50th, and 95th percentile head and neck ATDs. Load predictions from the 5th and 50th percentile models compared well with results from impact sled tests conducted at the Air Force Research Laboratory. However, the 95th percentile model, that of a Hybrid III large male ATD, did not correlate as well. To improve the FEM correlation with physical ATD responses from the sled test data, the NESC assessment team investigated differences in head and neck geometry, scaling, mass properties, and material properties between the 50th and 95th percentile ATDs. The team then updated geometry and mass properties to better match the physical ATD and conducted an optimization study to determine material properties. Finally, the team assessed correlation of the updated FEM against existing head-neck test data. This improved the 95th percentile model's predictive accuracy under lateral, rear, and frontal impact conditions and increased confidence in its use for occupant protection evaluation of large male Orion crew module occupants.



Data from ATD sled impact tests (top row) are used to anchor FEM models.

This work was performed by LaRC and JSC.
NASA/TM-2019-220412

COPV Overwrap Testing

During their construction, composite overwrapped pressure vessels (COPV) undergo wet winding and cure processes of composite strand material over a metallic pressure vessel liner that can affect the delivered overwrap material properties. The Commercial Crew Program (CCP) was evaluating a COPV redesign and requested the NESC provide independent mechanical and physical property testing of the vessel's overwrap material. The NESC assessment team focused their testing on three main areas: axial tension in the direction of the cylinder axis, through-thickness compression, and dynamic mechanical analysis testing for in-situ glass transition temperature. The NESC team provided the mechanical and physical property test results to the CCP to aid in structural analyses needed for the COPV's flight certification.

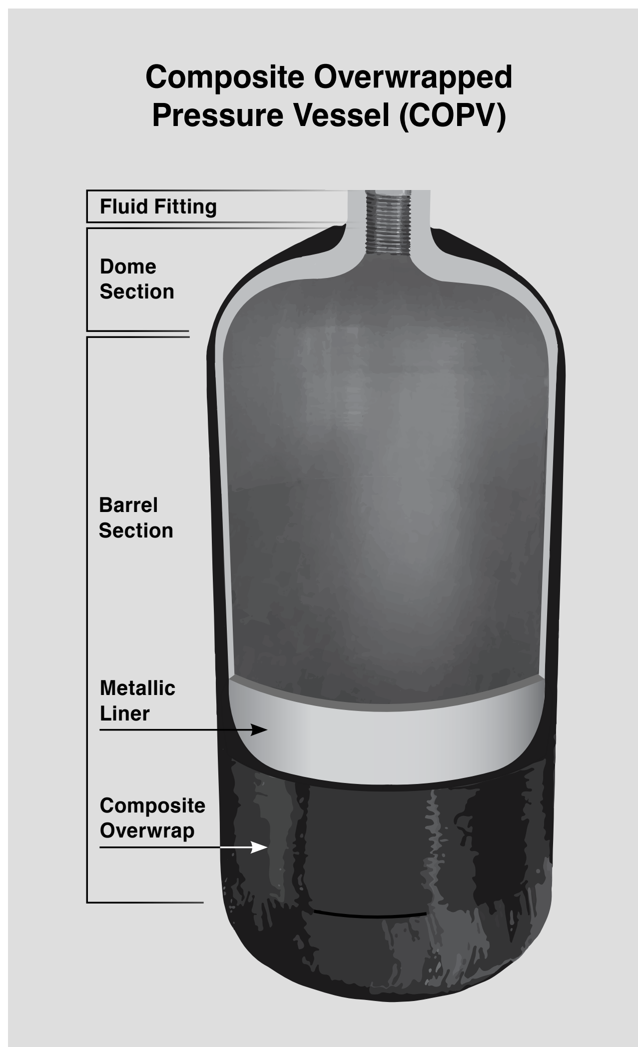
This work was performed by KSC, LaRC, WSTF, and MSFC.

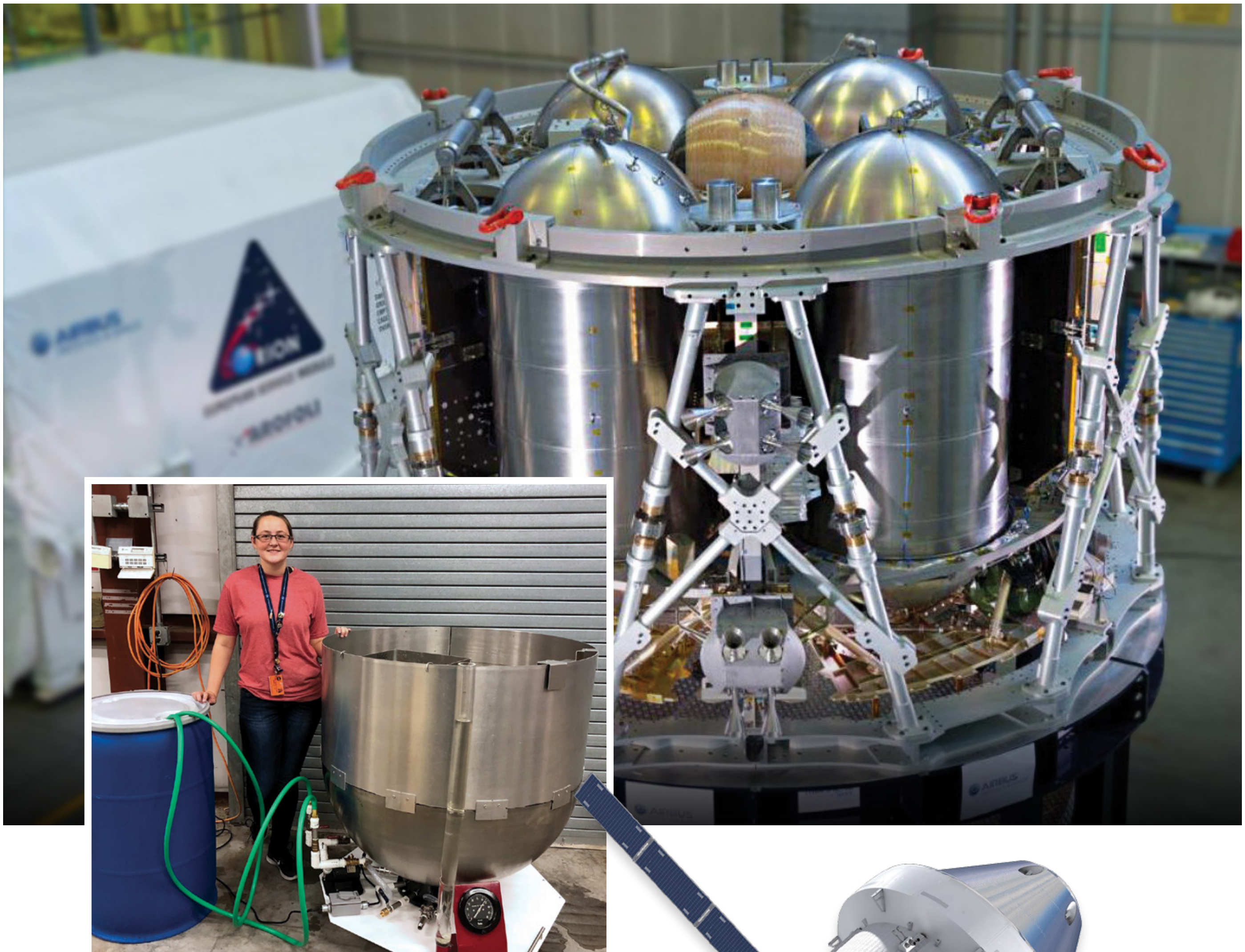
Stress Rupture of COPV Composites

COPVs used in spacecraft and launch vehicles are subjected to extreme pressures, loads, and temperature changes during lift-off as well as the harsh on-orbit environments of space. With deep space missions on the horizon, understanding how COPVs react under these conditions is crucial to mission safety. The CCP requested support from the NESC as CCP providers develop new and unique approaches for COPV development and use. In response, the NESC conducted and completed an assessment of the stress rupture reliability of COPVs immersed in cryogenic fluids. As no stress rupture data existed for this configuration, the NESC team developed a test approach to provide sufficient data to understand stress rupture in carbon fiber strands immersed in cryogenic fluids as compared to room temperature stress rupture strand data. In addition to the CCP, the new data can support other NASA programs and projects.

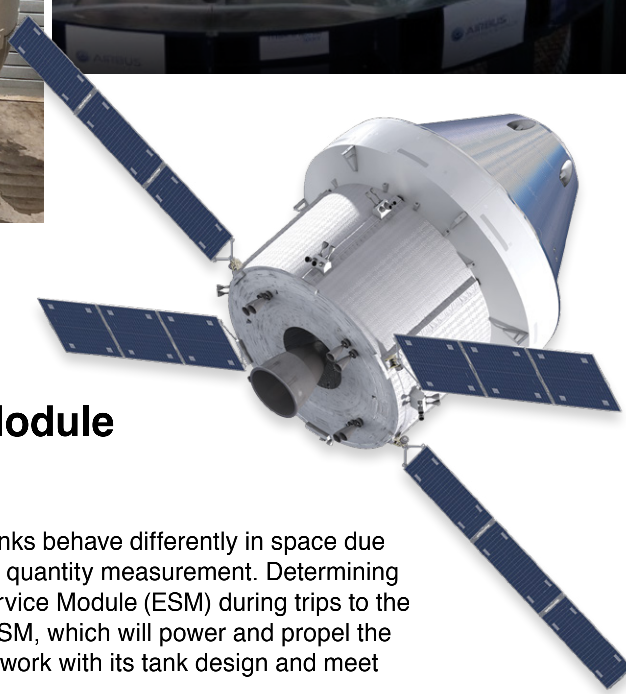
This work was performed by LaRC, JPL, MSFC, GRC, and WSTF.

COPVs experience an effect known as stress rupture, where the fibers experience degradation as a function of time, potentially resulting in a sudden overwrap failure and likely catastrophic pressure vessel failure. Shown is stress rupture testing of a carbon fiber strand at room temperature.





Intern Samantha Bell (KSC) collecting data on the Ultrasonic Level Sensor Mock Tank.



Feasibility of Ultrasonic Level Sensors for European Service Module MKII Propellant Tanks

Fluids used in launch vehicle and spacecraft propellant tanks behave differently in space due to the lack of gravity needed to settle the liquid for precise quantity measurement. Determining propellant quantity in the Orion spacecraft's European Service Module (ESM) during trips to the Moon or deep space will be especially challenging. The ESM, which will power and propel the spacecraft, requires a propellant sensing method that will work with its tank design and meet certain constraints such as no tank penetrations.

Building on a previous assessment that investigated ultrasonic instrumentation, the NESC researched several ultrasonic techniques that were potential candidates for the ESM. The NESC evaluated these nonintrusive techniques to gauge the ultrasonic signal's ability to discern liquid level or the presence of gas or liquid. The team also employed a mock-up propellant tank to test signal-to-noise performance, ability to distinguish false negatives, and understand signal attenuation in propellants versus water.

This work was performed by GRC, KSC, and WSTF.

Capsule Dynamics Comparison

The CCP, the Orion MPCV Program, the NESC, and SpaceX collaborated to perform an experimental evaluation of the dynamic stability characteristics of the Dragon 1 and Dragon 2 vehicles during entry, descent, and landing using the LaRC 20-foot Vertical Spin Tunnel. Capsule-shaped reentry vehicles tend to be unstable during freefall descent. Dynamic capsule stability is challenging to predict, with aerodynamic damping a primary quantity of interest because it affects flying qualities and parachute deployment parameters. A series of tests were conducted to collect the aerodynamic data that allowed Dragon spacecraft dynamic characteristics to be compared directly with data already acquired for the Orion crew module (CM) and Orion parachute test vehicle (PTV). The wind tunnel test included the use of static force and moment, forced oscillation, and free-flight test techniques. Six-component strain gauge balance and surface pressure measurements were taken during the static and forced oscillation methods, while the free-flight method used video and photogrammetry to quantify capsule dynamics. Adding more configurations to the suite of vehicles tested under identical conditions, along with future flight performance data, will have substantial value to NASA, SpaceX, and industry as a whole.

This work was performed by LaRC and JSC.

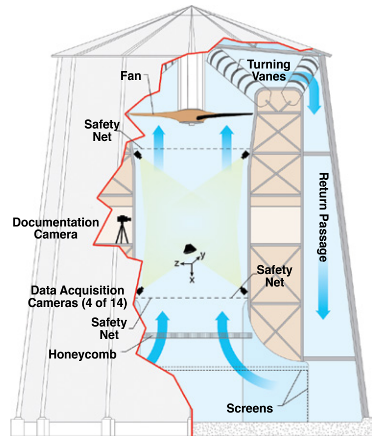


Illustration of LaRC 20-foot Vertical Spin Tunnel.

Capsule models of identical scale were used for direct comparison of results.

Commercial Crew Aerodynamics Peer Review

The design of launch vehicles and spacecraft for the CCP includes the development of aerodynamic databases that predict the performance of these vehicles throughout their flight envelope. Their development involves significant analytical and computational analysis as well as wind tunnel and flight testing. To provide CCP with an independent assessment of the approach, practices, and status of commercial crew spacecraft aerodynamic database development, the NESC assembled a team of aerodynamics experts to provide a more in-depth investigation of strategies, techniques, and data collected and synthesized to evaluate progress in developing this important flight component. The assessment included document and data reviews and evaluation of aerodynamic predictions and databases developed from those predictions for the commercial spacecraft, launch vehicle, and abort vehicles.

This work was performed by LaRC, MSFC, JSC, and KSC.

Evaluating Materials and Processes Issues

NASA Standard 6016, *Standard Materials and Processes for Spacecraft*, is directed toward materials and processes (M&P) used in the design, fabrication, and testing of spaceflight hardware. A series of potential M&P issues prompted a request to the NESC to review and evaluate best practices for spacecraft hardware development, NASA policies, and cross-discipline engineering engagement. Key items reviewed by the NESC team included: center management practices for spaceflight hardware development and crossdiscipline engineering engagement; systems engineering processes focused on the use of M&P expertise; and center M&P discipline capability relevant to the NESC assessment scope. The assessment examined how M&P discipline expertise from each center is planned for and engaged throughout the project development lifecycle. The assessment team interviewed engineering managers, program and project managers, chief engineers, and mission system engineers to identify common practices associated with how flight centers execute projects, from concept development and proposal through each design phase, including flight article qualification and acceptance. The team determined that NASA programs and projects would benefit significantly from greater M&P insight early during the formulation phase and throughout the design cycle to establish future technical needs and required M&P capabilities.

This work was performed by KSC, GSFC, LaRC, and JSC. NASA/TM-2018-22029

Independent Verification of SLS Block 1 Prelaunch, Lift-off, and Ascent Gust Methodology and Loads

The NESC was engaged in a multi-year, four-part study to provide the Exploration Systems Development (ESD), Orion MPCV, SLS, and EGS Programs with a verification of the loads predicted to be induced on the vehicles during prelaunch stacking and rollout, lift-off, and ascent gust phases. The effort was a step in evaluating the structural integrity of the vehicles to ensure crew safety. Prelaunch stacking/cryogenic shrinkage analyses were addressed first, followed by study of the ascent gust analysis methodology and loads. Both parts were completed in FY18.

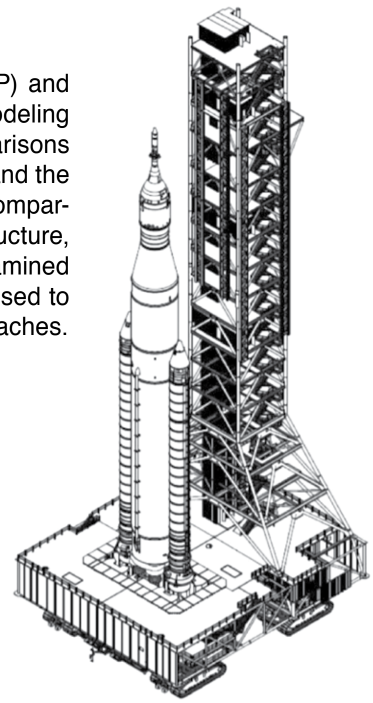
Efforts in FY19 focused on study of rollout and lift-off. Rollout studies used prelaunch stacking analysis model results from the FY18 studies to develop an SLS integrated system model that was verified and then subjected to rollout loads and sensitivity analyses for several vehicle parameters.

The lift-off studies focused on two primary areas. The first was an updated impact assessment on the SLS prelaunch stacking and cryogenic shrinkage loads using a revised Mobile Launcher (ML) FEM. The revised model included design modifications to the ML, which in turn could affect preloads. The second was an investigation of the nonlinear lift-off pad separation effects on the vehicle system using a set of instantaneous pad release constraints to assess the "twang" and decay time due to stacking and cryogenic shrinkage preloads.

This work was performed by GRC, JSC, LaRC, KSC, and GSFC.
NASA/TM 2019-22027, NASA/TM 2019-220294

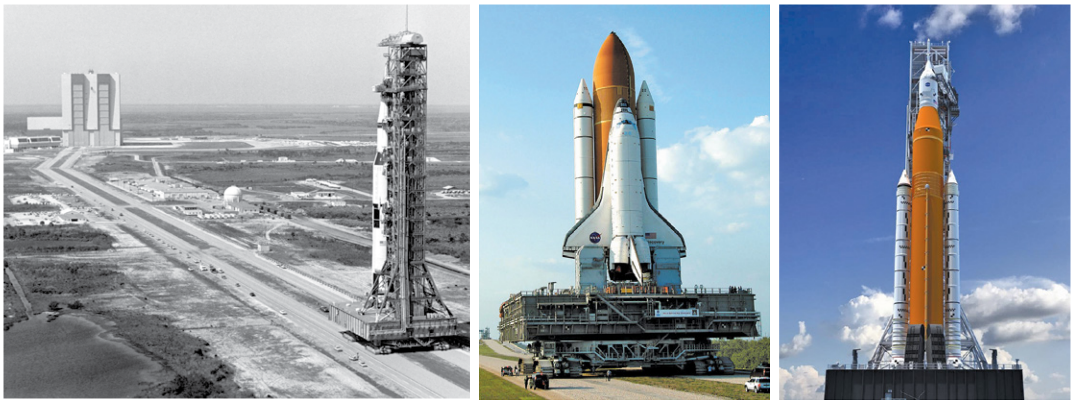
Artist conception of the SLS and ML on the Crawler Transporter during rollout to the launch pad.

EGS Mobile Launcher Structures Model Peer Review



Beginning with the Apollo Program in the 1960s, NASA has used mobile launch platforms (MLP) and crawler transporter (CT) vehicles to stack, move, and launch human-rated spacecraft. Current modeling and analysis of the SLS ML structure (a modified MLP) includes as-built versus as-modeled comparisons that also include increases in overall weight. Structural modification options are being considered and the NESC was requested to support EGS and EGS Engineering in this process. The NESC provided comparative review of various structural finite element models critical to the SLS Program launch infrastructure, concentrating on those of the ML and the Vehicle Assembly Building (VAB). These reviews examined modeling approaches used by different codes for specified design loads. The models were exercised to provide results suitable for direct comparison or evaluation of the differing model features or approaches.

This work was performed by LaRC, KSC, ARC, and JSC.

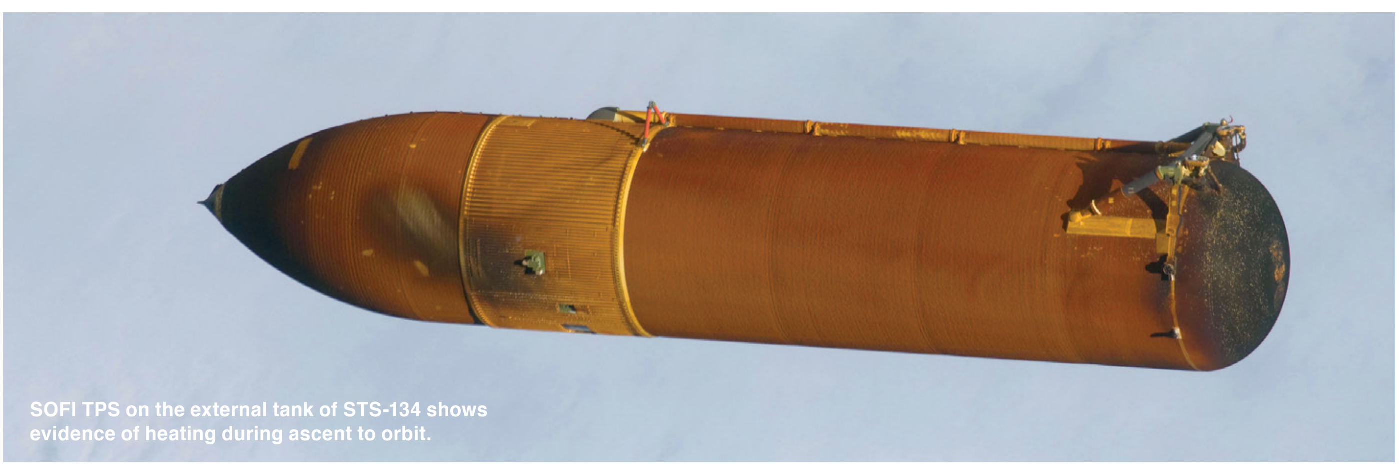


From left: Apollo/Saturn-V and Space Shuttle on MLP during rollout to launch pad from the VAB. Concept of Orion/SLS Block 1 on upgraded MLP.

Spray-on Foam Insulation Testing

Spray-on foam insulation (SOFI) for use as a thermal protection system (TPS) was developed in the 1960s for the cryogenic tanks of launch vehicles, such as those of the Saturn V rockets. Since then, SOFI TPS has evolved, undergoing many formulation changes during the Space Shuttle Program to that used today on the United Launch Alliance Atlas V and Delta IV and on the SLS launch vehicles. The NESC recently reviewed material characteristics and properties of SOFI used within the CCP, evaluating storage and transportation methods, spray processes, and net properties of ideal SOFI applications. The assessment also examined uniformity and consistency in applied foam properties and potential effects on the insulation characteristics. The NESC analysis provided additional confidence in SOFI materials used on CCP provider vehicles.

This work was performed by KSC, MSFC, and LaRC. NASA/TM-2018-220263

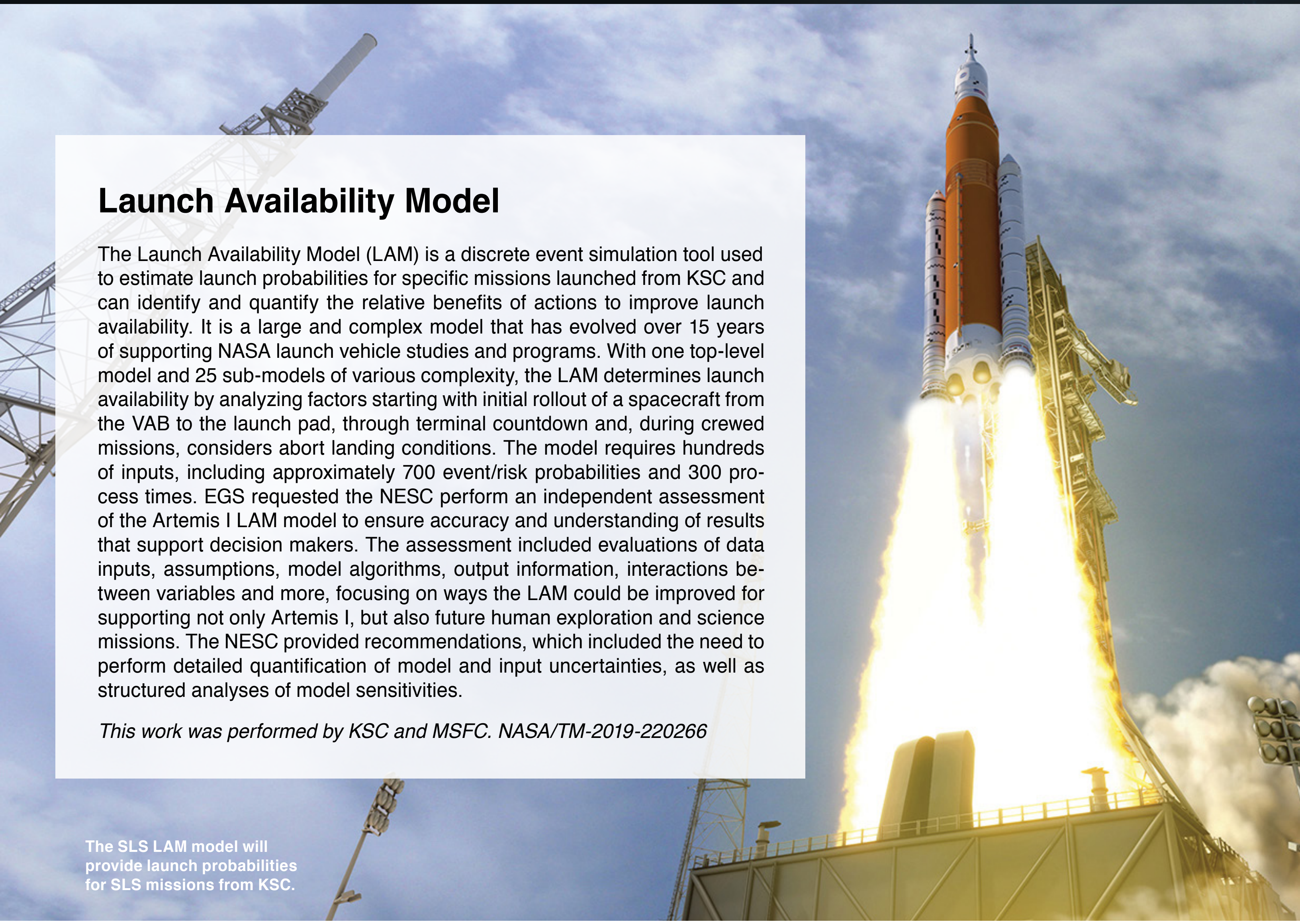


SOFI TPS on the external tank of STS-134 shows evidence of heating during ascent to orbit.

Launch Availability Model

The Launch Availability Model (LAM) is a discrete event simulation tool used to estimate launch probabilities for specific missions launched from KSC and can identify and quantify the relative benefits of actions to improve launch availability. It is a large and complex model that has evolved over 15 years of supporting NASA launch vehicle studies and programs. With one top-level model and 25 sub-models of various complexity, the LAM determines launch availability by analyzing factors starting with initial rollout of a spacecraft from the VAB to the launch pad, through terminal countdown and, during crewed missions, considers abort landing conditions. The model requires hundreds of inputs, including approximately 700 event/risk probabilities and 300 process times. EGS requested the NESC perform an independent assessment of the Artemis I LAM model to ensure accuracy and understanding of results that support decision makers. The assessment included evaluations of data inputs, assumptions, model algorithms, output information, interactions between variables and more, focusing on ways the LAM could be improved for supporting not only Artemis I, but also future human exploration and science missions. The NESC provided recommendations, which included the need to perform detailed quantification of model and input uncertainties, as well as structured analyses of model sensitivities.

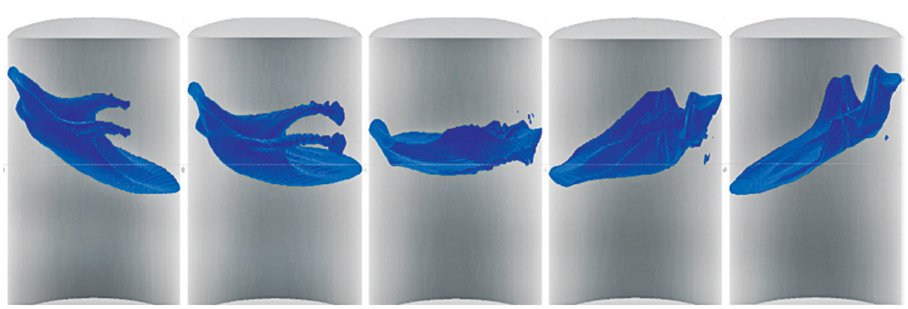
This work was performed by KSC and MSFC. NASA/TM-2019-220266



The SLS LAM model will provide launch probabilities for SLS missions from KSC.

Nonlinear Slosh Damping Analysis for Launch Vehicles

The liquid propellant in the fuel tanks of launch vehicles will slosh in flight, and adequate damping of this sloshing motion is critical to maintain control and prevent interference or damage to the vehicle and its systems. Traditional stability analyses of launch vehicle flight controls typically employ a linear model for damping, but they cannot account for the increase in damping that occurs with increasing wave amplitude, which is a nonlinear effect.



Simulation of slosh in a cylindrical tank.

To aid the SLS Program, the NESC developed nonlinear slosh damping models through a combination of computational fluid dynamics, testing with baffled and bare subscale tanks, and extensive analysis. Emphasis was placed on developing models for cylindrical as well as SLS core stage and Exploration Upper Stage liquid oxygen propellant tanks. The new models provide design flexibility to enhance launch vehicle flight control performance or increased robustness in control-structure interaction. Increased damping from the flight controls could also be leveraged to reduce structural design requirements, which would lower design and manufacturing costs and save weight in fewer or smaller baffles.

This work was performed by MSFC, GSFC, KSC, and LaRC. NASA/TM-2019-220278

Priority 2

In-Progress Assessments

- Human Error Analysis Guide
- Launch Abort System Risk Mitigation
- CCP Ascent Stability
- Issues with Qualification of Radiographic NDE Techniques
- CCP Postflight Reference Radiation Environments
- Independent Review of Analysis to Support Midpoint Monitoring in Batteries
- Independent Models of the SLS Hydrogen and Oxygen Pressurization Systems
- Parker EPR E0515 O-ring Material Obsolescence
- Mobile Launcher Independent Model Verification
- Material Compatibility and EAC Data for Metals in Hypergolic Propellants
- Characterization of Thick Section Aluminum-Lithium 2195 Natural Aging
- Lift-off Modeling and Simulation of T-0 Umbilicals for SLS
- Autonomous Flight Termination System
- CCP Main Parachute NDE
- CCP Provider Parachute Pack Ground Extraction Testing
- Spacecraft Safety Equipment
- Aerodynamic Buffet Flight Test
- Aerospace Valve Industrial Base and Acquisition Practices
- CCP Provider Separation System
- Human Factors Analysis of Test Stand Operations
- Thermocouple Interference During High-Speed Earth Entry
- Propellant Tank Safe-Life Analysis
- Lead H2 Pop During SLS RS-25 Start
- Viscous Effects on Launch Vehicle Ground Wind-Induced Oscillations
- Evaluation of Occupant Protection Requirement Verification Approach by CCP Partners
- NESC Peer Review of ESD Integrated Vehicle Modal Test, Model Correlation, DFI, and Flight Loads Readiness
- SLS Program Block I Booster Element Alternate Internal Insulation Risk Reduction
- Orion Titanium Hydrazine Tank Weld - Environmentally Assisted Cracking
- Infrared Laser Sensor Technology Readiness & Maturation
- Risk Reduction of Orion Government-Furnished ECLS
- Effects of Humidity on Dry Film Lubricant Storage and Performance
- Composite Pressure Vessel Working Group
- Stress Ruptures COPV
- 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 MPCV Aerodynamic/Aerothermal Database Models and Methods

In-Progress Support Activities

- CCP Provider Water Landing Structural Design Reliability
- MPCV Welded Coupon Autofrettage Crack Growth Tests
- CFM Feasibility Assessment for NTP
- Smart Initiator Redesign Support
- Risk of Alternative Pyro Lot Acceptance Test Plan
- Mars 2020 Wheel/Flexure Stiffness and Strain Capacity
- Review of SLS SOW
- SE&I Support to CCP DCRs
- SLS FTS Battery Cell-Out Test Procedure
- Orion, NDSB2, and Gateway Material Electrical Properties
- NASCAP Integrated Spacecraft Charging Analysis
- Service Module Pressure Control Assembly
- Active Mass Translator on Near-Earth Asteroid Scout
- EGS Crew Module Test Article Design Peer Review
- Orion Spacecraft Low-g Slosh Performance and Stability Impact Investigation
- Pegasus ICON Mission
- ESD Support Task for Dynamic System and Flight Test Analysis and Evaluation
- Orion Crew Module/Service Module Separation Nut Test Fixture Failure
- MAF Nonconformance Reporting and Corrective Action
- WFF Super Pressure Balloon Data Acquisition Design
- Orion CM Recovery During Underway Testing and Artemis I
- Orion Artemis II Spectrometer
- Mars 2020 Heatshield Structural Failure Review
- Power Electronics Technical Support for Electric Propulsion
- Hydrodynamics Support for Orion CM Uprighting System
- Adiabatic Demagnetization Refrigeration on SOFIA Science Instruments
- Waterflow Pulse Test Support to Develop RL-10 Pogo Model Propulsion Terms
- CCP Parachute Flight/Ground Tests and Vendor Packing/Rigging Activities
- Super Resolution Post Processing of Air-to-Air Imagery of CCP Provider High Altitude Parachute Test
- SLS Booster Nozzle Throat Plug Debris
- ORION CM/SM Separation Bolt Life Issue
- NOVICE Support to LSP and CCP Radiation
- Accelerance Decoupling for Modal Test
- Support for SLS Design Certification Review
- Ascent Abort-2 Independent Review Team
- Bond Verification Plan for Orion’s Molded Avcoat Block Heatshield Design

Priority 3

Known Problems Not Being Addressed by Any Project

Completed Assessments

Human Systems Integration for Safety-Critical Range Operations at Wallops Flight Facility

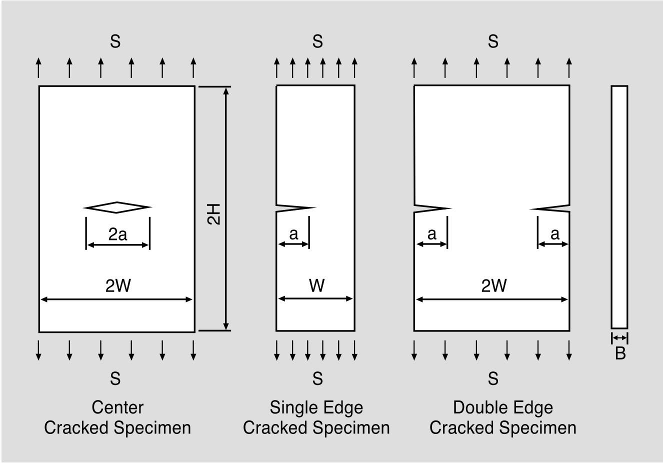
The Wallops Flight Facility (WFF) provides launch capabilities ranging from suborbital sounding rockets to large cargo vehicles carrying supplies to the ISS. The WFF is undergoing a major upgrade to its mission graphics system and flight termination system within the Range Control Center range safety room. These safety-critical systems facilitate rapid and accurate decision making on the part of highly trained users to maintain safe launch operations. In addition, the range safety room is undergoing planned upgrades. There is no NASA policy or process to ensure that human systems integration (HSI) and human factors design principles are applied or implemented.

To assist the WFF Range Safety Operations in identifying efficiencies, an NESC team interviewed Range Safety Team personnel at various test sites and examined operational observations, standards/best practices, and control room documentation from the Department of Defense, Federal Aviation Administration, and Nuclear Regulatory Commission. The team provided recommendations on areas that would benefit from a systematic consideration of HSI standards and best practices and a dedicated HSI professional to assist in the design/evaluation of upgrades.

This work was performed by ARC and LaRC. NASA/TM 2019-220411

Antares launches cargo to ISS from the Wallops Flight Facility.

Implementation of Elastic-Plastic Crack Instability Analysis Capability (J-A) into WARP-3D Code



Different specimens analyzed for verifying J-A prediction methodology.

Characterization of the stress/strain field near a crack-tip is the foundation of fracture mechanics and critical for achieving reliable fracture control analysis results for programs that require fracture control analysis. The vast majority of fracture mechanics analysis performed in support of fracture control rationale is carried out using reasonably conservative values for initiation fracture toughness derived from high constraint test geometries and stress intensity factors, K, based on linear-elastic material assumptions. However, when elastic-plastic behavior occurs, linear elastic assumptions are no longer valid and use of K to characterize the stress field is not appropriate. In ductile materials the elastic-plastic crack-tip stress fields are characterized by the Hutchinson-Rice-Rosengren (HRR) field, and the J-integral is commonly used to characterize amplitude of the HRR field. However, as the external load increases, yielding changes from small-scale to large-scale plasticity and usually a loss of constraint (i.e., reduction in the triaxial stress field along the crack front). The loss of constraint leads to the deviation of the crack-tip stress fields from that given by the HRR field, and the J-dominance will be gradually lost. Additional parameters are required in this situation to better quantify the crack-tip stress fields and predict fracture behavior.

The NESC conducted an investigation in an attempt to reduce conservatism and consider constraint specific toughness capability, ultimately implementing the two-parameter J-A fracture criterion into an elastic-plastic three-dimensional finite element analysis (FEA). The A constraint is the second parameter in a three-term elastic-plastic asymptotic expansion of the near-tip stress behavior. This required using J resistance curve data obtained from standard specimens that were adjusted to match the component versus test specimen constraint level (i.e., A constraint parameter). The FEAs were performed in an open source finite element code, WARP-3D, to obtain solutions for the A parameter for different specimen configurations. The investigation also included: validating the J-A implementation by comparison with the A parameter from literature data; conducting material characterization tests to quantify the material behavior and provide fracture data for validation of the J-A fracture criteria; and performing evaluations to establish if the J-A criteria can be used to predict fracture in a ductile metallic material. Results indicate the methodology can be used to calculate elastic–plastic J-A parameters for test specimens with a range of crack geometries, material strain hardening behaviors, and loading conditions, but will require additional research and maturation before implementation into flight certification fracture code.

This work was performed by ARC, JSC, LaRC, MSFC, and JPL. NASA/TM-2018-220115

Priority 3

In-Progress Assessments

- Characterization of Internal Insulation Thermal Performance
- 2nd NESC Lunar Dust Workshop
- Occupant Protection Testing
- Transient Combustion Modeling for Hypergolic Engines
- Shuttle Enterprise Main Landing Gear Fracture
- Parachute Reefing Line Cutter Modification & Qualification
- Need for Wireless EDL Instrumentation Validation
- Micro-Thrusters for Low-Jitter Space Observatory Precision Attitude Control
- Southern Hemisphere Meteoroid Environment Measurements
- Guidelines for Battery TR on Robotic Missions
- Auroral Charging Threat Assessment
- Creation of Agency Standards for Additive Manufacturing
- CubeSat Radiation Environments and ISS Radiation Dose Data
- Calorimetry for Large Format Li-Ion Cell TR
- Safe, High Power Li-Ion Battery Module Design
- Space Weather Architecture
- MMOD Pressure Vessel Failure Criteria
- Composite Overwrapped Pressure Vessel Life Test
- Rad750 Qualification Testing
- Shell Buckling Knockdown Factor Proposal

In-Progress Support Activities

- ACCP SET Requests S&I TDT to Support/Perform a TRA of the Lidar Instruments
- Advanced Weapons Elevator CVN-78
- Lunar-Lander Standing-Acceleration Limits Standards Development
- DART Spacecraft SmartNav Independent Review Team
- DARPA's Experimental Space Plane
- Revising NASA-HDBK-4002A
- Lunar Lander Mentor Team
- PAMELA Radiation Data Recovery
- 6 Degree-of-Freedom Trajectory Simulation with Integrated CFD Aerodynamics
- Completion of NASA-HDBK-5010A

Shell Buckling Knockdown Factor compression testing of lab-scale 31-inch-diameter composite cylinder at LaRC as part of scaling study with Delft University of Technology.

Status Update: Shell Buckling Knockdown Factor Project *(In-Progress)*

The Shell Buckling Knockdown Factor (SBKF) Project was chartered to develop and experimentally validate new analysis-based buckling knockdown factors for stability-critical metallic and composite launch vehicle structures. New knockdown factors for metallic structures were applied to the SLS core stage, which resulted in documented mass, cost, and schedule savings.

The current focus of SBKF is in developing buckling analysis approaches for sandwich composite cylinders that can be used to develop new buckling design factors. To support this development, a series of large-scale 8-foot-diameter test articles are being tested to validate these analyses. The third such large-scale test article was fabricated in March 2019 for testing in winter 2019, and the fourth test article was fabricated in September 2019 for testing in late summer 2020.

In addition, the sixth SBKF workshop was held in June 2019 with participation from both NASA and industry. These workshops are valuable to help ensure that the SBKF products are informed by and most beneficial to launch vehicle designers. In order to ensure that SBKF is working in the current state-of-the-art, a number of external collaborations have also been established with domestic and international partners in government, academia, and industry. As part of an effort to establish scaling laws for the buckling response of sandwich composite shells, the SKBF Project engaged in a collaborative effort with the Delft Technical University to test a 31-inch-diameter composite cylinder, which was a scaled-down version of the 8-foot-diameter shells tested in June 2019.

Photos: Members of the SBKF Team are developing new knockdown factors for sandwich composite cylinders.

Priority 4

Work to Avoid Potential Future Problems

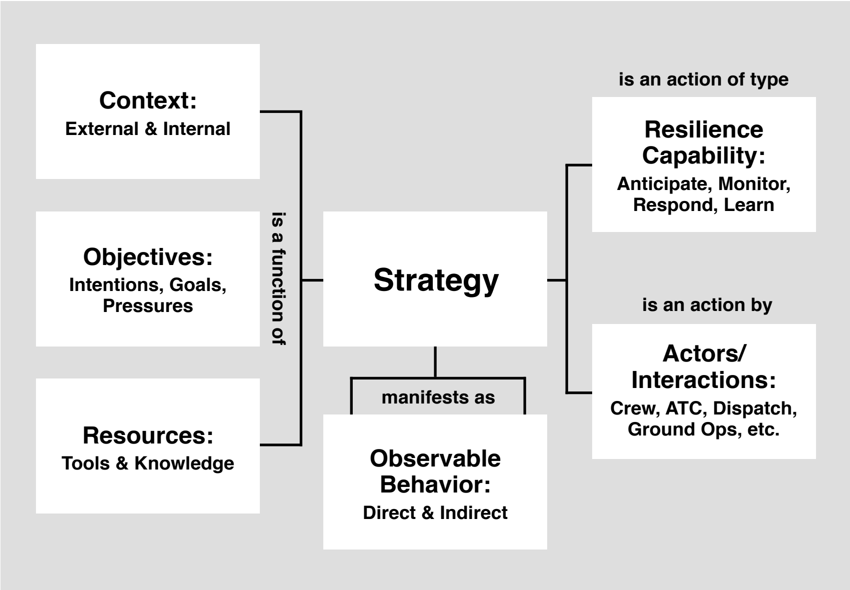
Completed Assessment

Human Performance Contributions to Safety in Commercial Aviation

While the overwhelming majority of commercial aviation flights results in safe and successful outcomes, the contribution of humans to those successes is poorly understood. Pilots, air traffic controllers (ATC), and other front-line personnel perform countless correct judgments and actions, which are often the difference between an accident and a non-event. Automation initiatives that reduce routine human involvement in civil aviation transport could introduce unrecognized and unknown risks without an adequate understanding of the day-to-day human contribution to safety.

The NESC Human Factors Technical Discipline Team identified this topic as an unrecognized critical Agency need. To assess these human performance contributions, the NESC team used a broad range of existing aviation data sources and commercial pilot interviews to identify resilient behaviors and strategies to promote them. This included identification of possible metrics and data gaps for capturing human contributions to safety. The team provided recommendations to address the definition of safety and the associated actions and tools that promote resilient performance of operators; to characterize strategies that support resilient performance methods for exploring and refining those strategies in existing data; and for capturing and analyzing new data on resilient operator performance.

This work was performed by ARC and LaRC.
NASA/TM-2018-220254



Strategy framework for identification of factors that reflect resilient actions.

Priority 4

In-Progress Assessments

- FPMU Data Processing Algorithm Development and Analysis
- Badhwar-O'Neill Galactic Cosmic Ray Model Improvements
- Updating RefProp with Nitrogen Tetroxide Properties
- Wire and Wire Bundle Ampacity Testing and Analysis
- Solderless Interconnects and Interposers
- EEE Parts Copper Wire Bonds for Space Programs

In-Progress Support Activities

- Air Force Research Laboratory/Space Technology Mission Directorate Advanced Rad-Hard Memory
- State of In-Space Propellant Tanker/Transfer Technology

Priority 5

Work to Improve a System

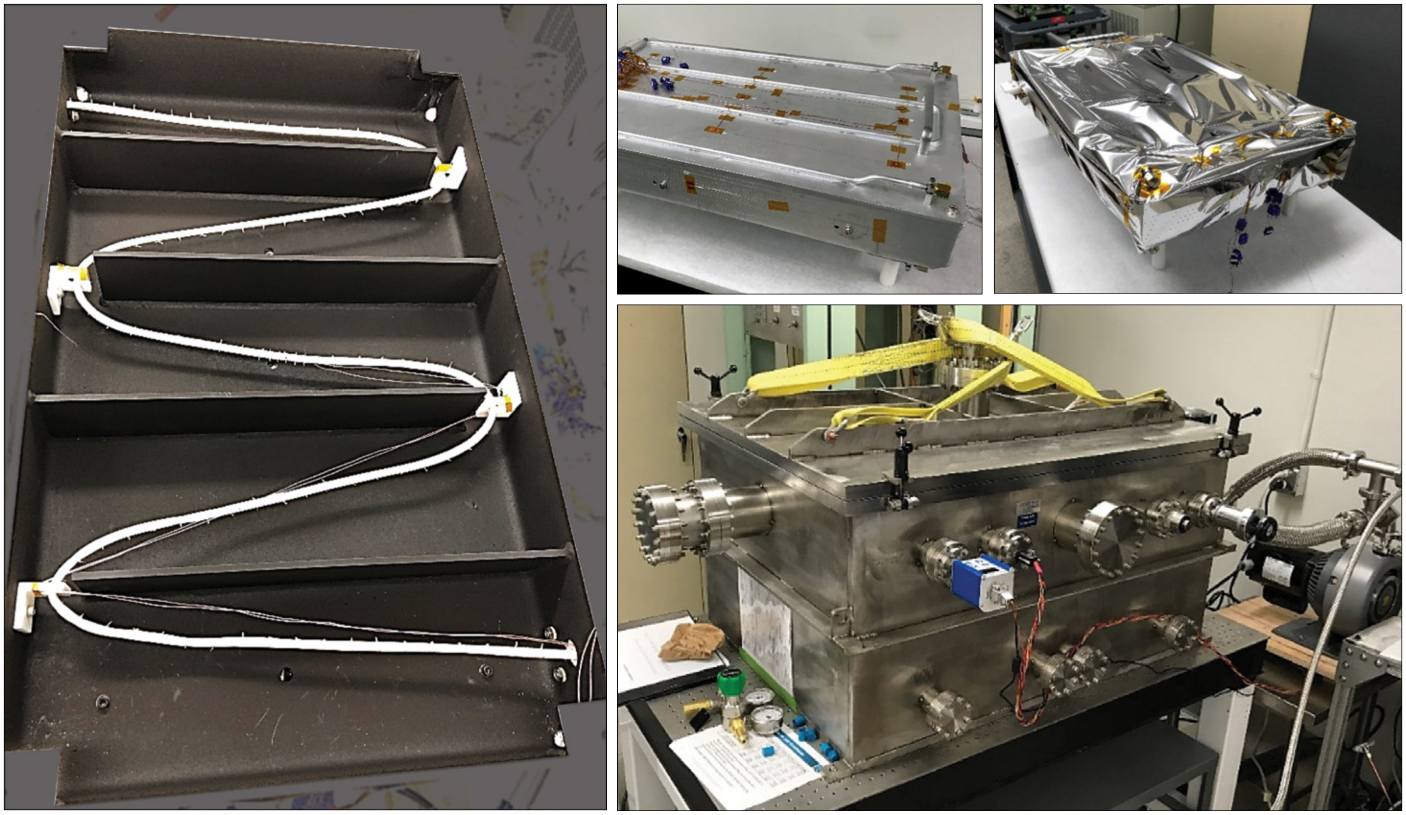
Completed Assessments

Re-Architecting the NASA Wire Derating Approach for Human Space Flight Applications

Design of wiring for aerospace vehicles relies on an understanding of “ampacity,” which refers to the current carrying capacity of wires, individually or in wire bundles. Designers rely on aerospace standards (e.g., JPL D-8208 and AS50881) to derate allowable current flow to prevent exceeding wire temperature limits due to resistive heat dissipation within the wires or wire bundles. These standards often add considerable design margin and are based on empirical data. To assess the feasibility of developing physics-based and regression thermal models of single wires and wire bundles, the NESC completed a pathfinder study to develop a test apparatus for wire testing, which could replace reliance on standards.

The NESC assessment team developed and demonstrated a preliminary physics-based thermal model and developed a test facility for accurately measuring the thermal profile of single wires and wire bundles. Thermal model predictions were validated with completed experimental testing, and the test facility collected wire conductor temperature data under vacuum and atmospheric conditions and varying environmental temperatures and currents for the two most common spacecraft wire types. The team also developed a preliminary regression model. Based on successful results, the NESC is planning a more comprehensive follow-on assessment.

This work was performed by JSC, KSC, JPL, MSFC, WSTF and GSFC.
NASA/TM-2018-220114

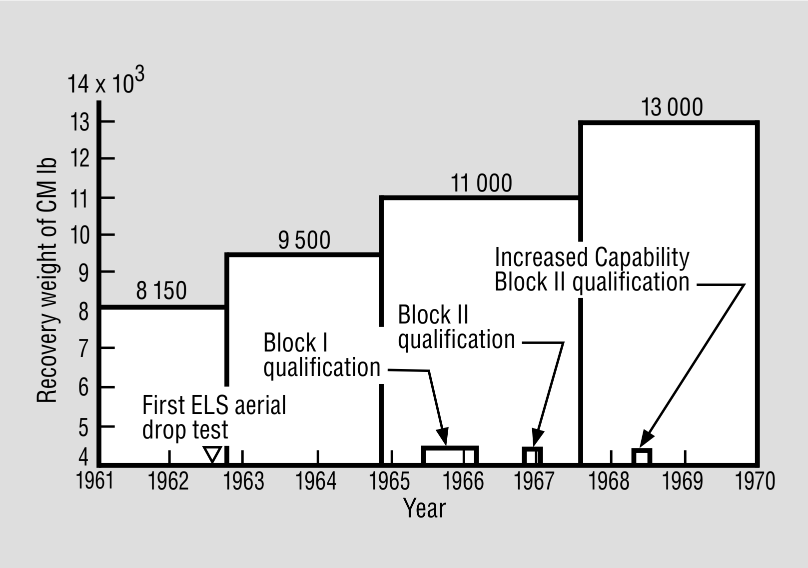


Clockwise from left: A wire bundle test article is placed in a temperature-controlled shroud, then insulated, and finally sealed in a chamber for ampacity/temperature rise measurements as current is applied in air or under vacuum conditions.

Reliable Method to Reason About Mass Growth

Experience has shown that unexpected mass growth occurs on many NASA programs and projects and sometimes is cause for significant design changes and chaotic behavior. Standards and practices are available for managing risks associated with mass growth, but they are not always applied programmatically and/or contractually in a timely or thorough manner. The NESC conducted an assessment to address improvements in mass properties estimation and management via learning from past projects, improving process rigor, and managing mass properties in an environment of threats and opportunities. The multi-pronged approach included analyzing and capturing mass growth data from programs and projects and their processes for mass margin management. The team's evaluation provided data and analysis to support reasoning about mass margins and associated risk for current and future high-priority programs and projects.

This work was performed by GSFC, JPL, MSFC, LaRC, and JSC.

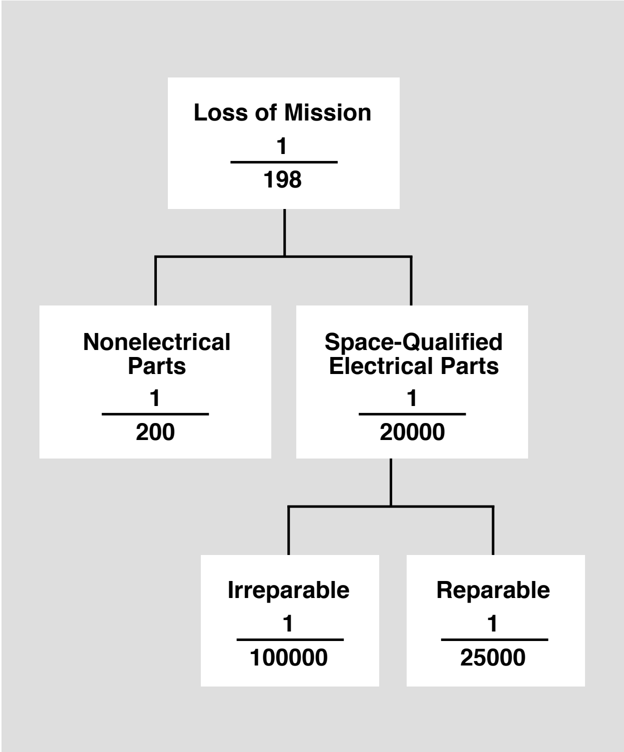


The Apollo crew module mass increased by almost 60% before the final configuration was qualified for flight, having significant impact on the design and qualification of the Earth landing system (ELS).

Radiation Single Event Effects Impact on Complex Avionics Architecture Reliability

Whether in terms of size, weight, power, speed, precision, or a range of other metrics, the advantages of commercial state-of-the-art (SOTA) electrical, electronic, and electromechanical (EEE) parts are becoming apparant for space missions to achieve ambitious performance goals. However, most of these parts are designed for terrestrial applications, and their use in space environments often introduces susceptibilities to single event effects (SEE) that may pose significant threats to mission success. Unless space mission design teams develop sufficient understanding of SEE susceptibilities and model their effects on a system, these fault and failure modes can overwhelm intended system-level reliability and safety, resulting in system failure. To support mission success in NASA missions contemplating employing commercial SOTA EEE parts that will be exposed to radiation environments, the NESC developed a set of guidelines for using system-level modeling to develop insights into system vulnerabilities before SEE becomes a significant threat to mission success. System-level modeling can explore system sensitivity to SEE rates and consequences when details of the performance of constituent parts remain uncertain, and can establish upper bounds on the SEE rates necessary for acceptable system performance. The guidelines also identify characteristics that may render a system particularly vulnerable to SEE and how to use the results of system-level modeling to optimize testing, analysis, and verification efforts in terms of system-level risk reduction. Reference NESC Technical Bulletin 19-1, available at nesc.nasa.gov. See page 30 for more information.

This work performed by LaRC and GSFC. NASA/TM-2019-220269



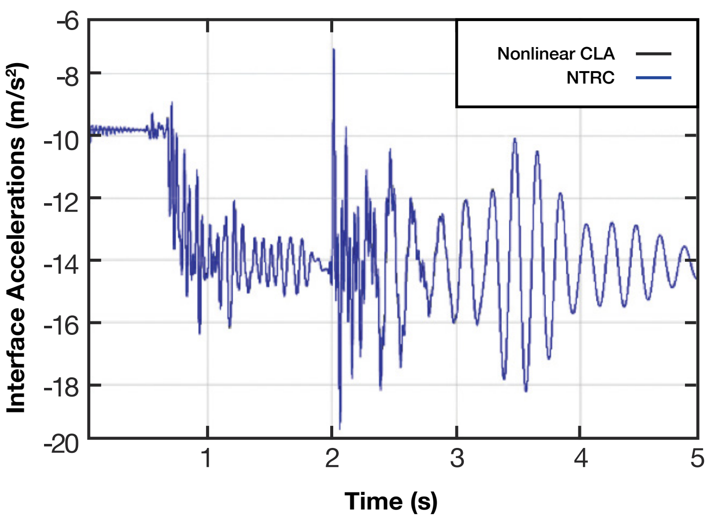
Use of space-qualified parts reduces electrical failure rates to 1/100 of that of nonelectrical components. Use of SOTA can increase the electrical part failure rates.

Fast Coupled Loads Analysis via Norton-Thevenin Receptance Coupling

To address the payload community's lack of accessibility to coupled loads analysis (CLA) results due to cost and schedule constraints associated with the standard CLA process, the NESC funded the study of an alternate method for performing launch vehicle/payload CLA called Norton-Thevenin Receptance Coupling (NTRC). NTRC provides a tool that payload developers can use to obtain launch loads at a fraction of the cost of a CLA at any time it is required in the payload design cycle. While NTRC is not intended to replace the formal load cycles performed by the launch vehicle (LV) provider, it will provide the ability to reduce the conservatism in defining preliminary design loads; assess the impact of design changes between formal load cycles; and perform trade studies. Parametric loads analyses are possible where many different design configurations can be evaluated with a minimum amount of data required from the LV provider.

NTRC condenses all the necessary information into the LV-to-payload connection points or boundary degrees-of-freedom (BD). The launch vehicle model is represented by its impedance at its BDs; its forcing functions are represented by the acceleration at those BDs when the payload is absent; and the payload is represented by its impedance at the same BDs. Payload responses are represented by transfer functions of selected responses to interface BDs. The NTRC methodology is exact in the frequency domain. Time domain replication and accuracy is outstanding. In order to deploy NTRC Agency wide and get the return on investment, a second phase is envisioned to benchmark the whole set of CLA events for the Agency's most utilized launch vehicles.

This work was performed by GRC, GSFC, LaRC, KSC, and JSC. NASA/TM-2019-220270, NASA/TM-2018-220091, NASA/TM-2018-220101



Interface accelerations in LV thrust direction capturing all relevant characteristics of pad separation CLA.

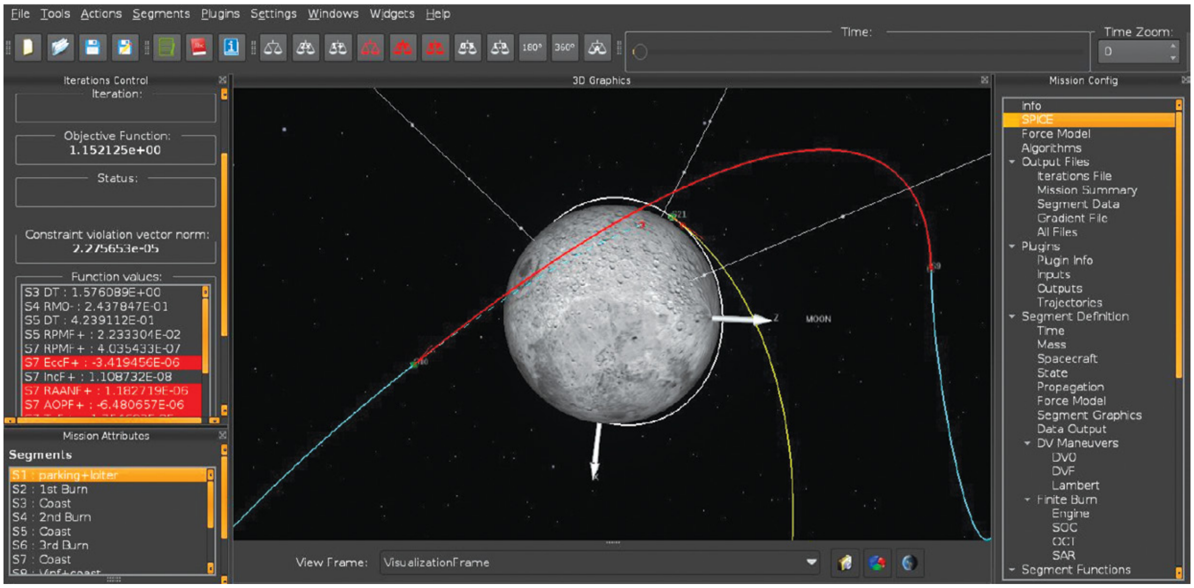
Artist's rendering of SLS Block 1/Orion.

Improved Design and Optimization of Complex Trajectories

NASA, industry, and academia use a suite of tools to study, design, and execute spacecraft missions. One of those tools is Copernicus, a spacecraft trajectory optimization and design analysis system that integrates state-of-the-art algorithms enabling analysts to design spacecraft missions to all possible solar system destinations. Copernicus has evolved to conform to current trends and requirements, and in version 5.0, the NESC developed updates and new capabilities that have resulted in significant improvements.

The upgrades include improved visualization, a modern graphical user interface toolkit, expanded and updated Python scripting language implementation, and an enhanced plug-in implementation. The task produced three independent platform versions for PC, Mac, and Linux that run natively on each respective platform. The updates and improvements are expected to provide enhanced mission optimization/performance and crew survivability and reduced mission risk for numerous human and science mission spaceflight programs.

This work was performed by LaRC, JSC, GRC, GSFC, and JPL.
NASA/TM-2019-220247



Copernicus running on Linux via a remote desktop client. The look and behavior of the tool is identical on Windows, Linux, and MacOS platforms.

Priority 5

In-Progress Assessments

- Profiling Toxic Lunar Dust Dissolution in Aqueous Environments
- Spacecraft Passivation Techniques
- Flight Mechanics Analysis Tools Interoperability and Component Sharing
- Flexible Multibody Dynamics Modeling for Space Vehicles
- Improvements to the Flight Analysis and Simulation Tool
- Deep-Space Climate Observatory Pulse Height Analyzer Data Analysis

In-Progress Support Activities

- Determining the Composition and Depth of the Lakes on Titan
- Defense Advanced Research Projects Agency - TRADES Study

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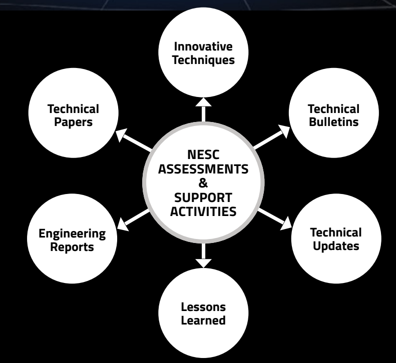
The NESC is engaged in activities to identify, retain, and share critical knowledge in order to meet our future challenges. To disseminate that knowledge to engineers - within NASA, industry, and academia - the NESC develops a wide variety of knowledge products that can be readily accessed including technical assessment reports, technical bulletins, video libraries, and more.



NESC Knowledge Products

Engineering Reports

The detailed engineering and analyses generated from each assessment are captured in comprehensive engineering reports and converted to NASA Technical Memorandums (TM) for permanent archive and access. For information on NESC reports, visit ntrs.nasa.gov and ntrsreg.nasa.gov.

Technical Bulletins

Critical knowledge captured from NESC assessments in the form of new engineering information or best practices in a one-page format. To view NESC Technical Bulletins, visit nesc.nasa.gov/nesc/technicalbulletins.

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The NESC Academy presents live and on-demand content from researchers, engineers, and field experts in 20 technical disciplines. The Academy hosts over 780 videos and webcasts containing interviews, tutorials, lectures, and lessons learned in an engaging format that features side-by-side video and slides, powerful search capabilities, downloadable lesson materials, and more. These lessons, many of which are publicly available, can be viewed at nescacademy.nasa.gov, with content exclusive to NASA employees available upon sign-in.

Subscribe to our mailing list to ensure you never miss an opportunity to learn from NASA engineers when we have upcoming webcasts or new lessons available.

Technical Updates

Annual summary of NESC assessment activities including lessons learned, technical bulletins, innovative techniques, discipline features, technical journals, and conference publications. To view NESC Technical Updates, visit nasa.gov/nesc/technicalupdates.

Lessons Learned

An Agency-level lessons learned database called the Lessons Learned Information System (LLIS) is used to capture important and broadly applicable lessons learned. NESC and Agency lessons learned can be found at llis.nasa.gov and nen.nasa.gov.

Innovative Techniques

Solutions developed from NESC assessments. nasa.gov/offices/nesc/innovativetechniques.html

Technical Papers

Written by members of the NESC and NESC Technical Discipline Teams to capture and convey new knowledge learned on NESC assessments. A list of NESC technical papers and conference proceedings is available at nasa.gov/nesc/technicalpapers.

Discipline Focus Articles

Discipline Focus articles highlight important information, gleaned from NESC assessments, which may benefit a wider audience. A list of overarching NESC featured articles is available at nasa.gov/nesc/features.

NESC Knowledge Products

The NESC engages 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 including technical assessment reports, technical bulletins, video libraries, and more.

Explore all NESC Knowledge Products online at NESC.NASA.GOV.

NESC Academy

NASA Engineering & Safety Center

A forum for the NASA community to gain critical knowledge to aid professional development and support the NASA mission.

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It presents live and on-demand content from researchers, engineers, and field experts in 20 technical disciplines relevant to the design, development, test, and operation of NASA programs and projects. It hosts more than 780 videos and webcasts containing interviews, tutorials, lectures, and lessons learned in an engaging format that features side-by-side video and slides, powerful search capabilities, downloadable course materials, and more.

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- **17 VIDEOS PUBLISHED FY19**
- **18 LIVE WEBCASTS FY19**
- **780+ TOTAL VIDEOS**
- **131,650 TOTAL VIEWS**

NESC Academy Contact:
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FY19 Most Viewed Videos by Discipline

Aerosciences	Aerodynamic Performance Testing
Avionics	FAA Overview: Software Certification for Avionics
Electrical Power	High Voltage Engineering Techniques for Space Applications: Part 1
Environmental Control/Life Support	Space Radiation Environments
Flight Mechanics	Standard Check-Cases for Six-Degree-of-Freedom Flight Vehicle Simulations
GNC	Overview of Spacecraft Attitude Determination and Estimation
Human Factors	Human Factors of Remotely Piloted Aircraft Systems: Lessons from Incident Reports
Loads & Dynamics	Shock & Vibration: 01 Natural Frequencies, Pt.1
Materials	Apollo 13 Pressure Vessel Failure
Mechanical Systems	Overview of Fastener Requirements in the New NASA-STD-5020
NDE	Intro to Probability of Detection (POD) for NDE
Passive Thermal	Short Course on Lithium-ion Batteries: Fundamental Concepts, Heating Mechanisms, and Simulation Techniques
Propulsion	Generalized Fluid System Simulation Program Training Course 01: Course Intro
Sensors & Instrumentation	Antimonide Based Infrared Detectors and Focal Plane Arrays for NASA Applications
Space Environments	(MOWG) NASA Robotic CARA Satellite State Estimate Covariance
Structures	Structural Analysis Part 1
Systems Engineering	Model-Centric Engineering, Part 1: Intro to Model-Based Systems Engineering

Technical Bulletins

Critical knowledge captured from NESC assessments in the form of new engineering information or best practices in a one-page format. NESC Technical Bulletins are available at nesc.nasa.gov.

Technical Bulletin No. 19-01

Avoiding Single Event Upsets in Commercial Parts Used in Space Applications

The current and former NASA Technical Fellows for Avionics have led several NESC assessments to better understand and quantify the risks of using commercial electrical, electronic, and electromechanical parts in space-based architectures. These complex architectures rely on highly integrated electronics that provide state-of-the-art functionality, but commercial components having high levels of functionality are potentially more susceptible to radiation that can result in single event upsets that may or may not be recoverable. Because the impact of single event effects (SEE) to system reliability are not always accounted for in analyses, this Technical Bulletin relays the best practices learned from NESC assessments to mitigate the effects of SEEs. The goal is to help the NASA avionics community better prioritize radiation testing to areas that will have the greatest impact on reliability.

Technical Bulletin No. 19-02

90/95 POD Radiography Concern for COPVs and Metal Tank Welds

Inspecting all-metal tanks and composite overwrapped pressure vessels (COPV) using radiography presents significant challenges, particularly when inspecting for cracks in the tank welds. Recent evaluations performed by nondestructive evaluation experts at JSC found that X-rays, which must penetrate two-wall thicknesses of a welded tank, cannot guarantee detection of a crack with the same level of reliability demonstrated in the typical single-wall test. This lack of visibility into the weld cracks can mean fracture risk is not fully understood. This Technical Bulletin aims to highlight that risk and suggests methods to better understand it until further research can determine more effective techniques for evaluating damage tolerance on these tanks.

Lessons Learned

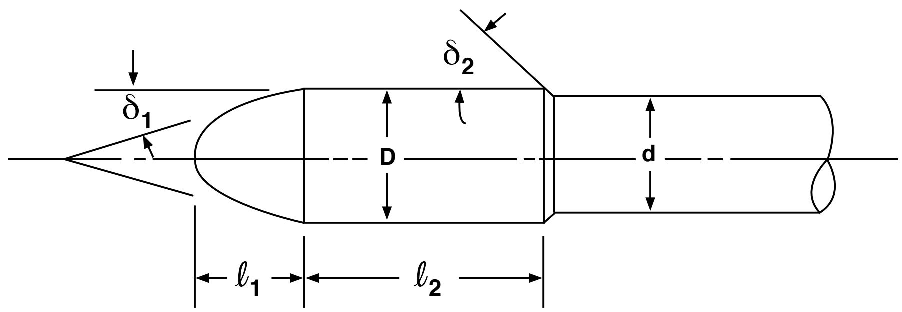
The NASA Lessons Learned Information System (LLIS) provides access to official, reviewed lessons learned from NASA programs and projects. These lessons have been made available to the public by the NASA Office of the Chief Engineer and the NASA Engineering Network. Each lesson describes the original driving event and provides recommendations that feed into NASA's continual improvement via training, best practices, policies, and procedures. Below are recent NESC contributions.

LLIS 25602

https://llis.nasa.gov/lesson/25602

Following Design Guidelines to Reduce Atmospheric Buffeting in Launch Vehicles

If NASA aerodynamic design guidelines for hammerhead payload fairings [Cole, H.A., Jr., et al.: Buffet During Atmospheric Ascent, NASA SP-8001, November 1970] are not followed, severe aerodynamic behavior may result, affecting controllability and structural integrity. Recently, vehicles of importance to NASA have not met the guidelines.



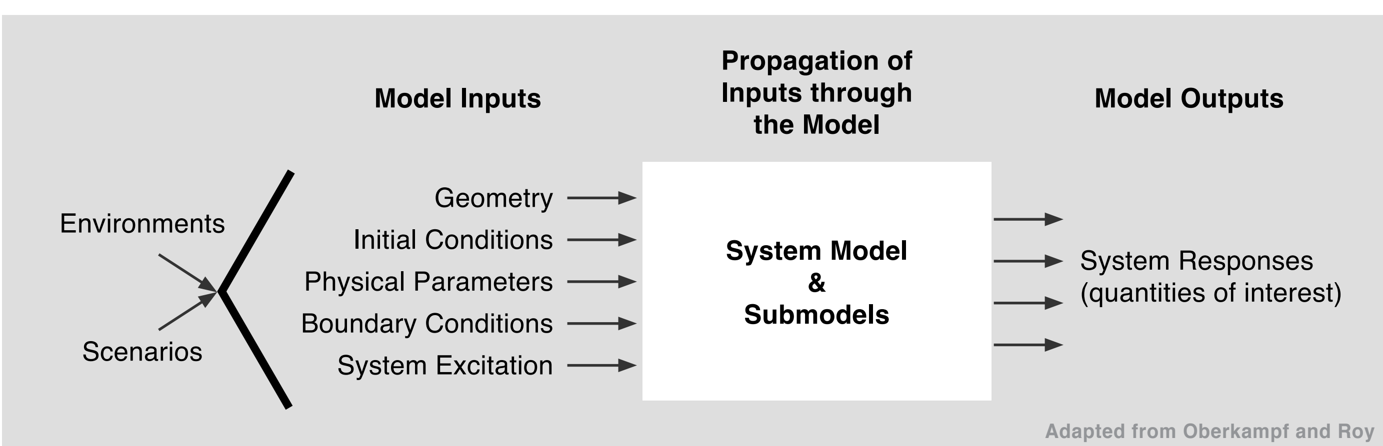
d = 0.9 D to 1.1 D	
$\ell_1 \geqq 0.80$ D	$\ell_2 > 0.80$ D
$\delta_1 \leqq 15$ deg	δ_2 not critical

LLIS 25509

https://llis.nasa.gov/lesson/25509

Contracting for Modeling and Simulation (M&S)-Based Analytical Services with Only the Analysis Results as Deliverables

NASA, on certain occasions, contracts for M&S-based analyses with few requirements, if any, for delivery of the M&S or other development or use artifacts along with the results from the analyses. While the costs for such contracts are lower, this practice provides an environment for potentially limiting the full and complete understanding of the model and data upon which the analyses are accomplished.



Richard W. Russell
NASA Technical Fellow
for Materials

Deceptively Complex: COPVs Remain a Challenge for Engineers to Unravel

Composite overwrapped pressure vessels (COPV) are ubiquitous at NASA. Found on launch vehicles and spacecraft, they are critical containers and suppliers of propellants and the elements required for life support. The NESC has invested significant time and resources to better understand how COPVs work, and more importantly, how these complex, high-pressure storage systems can fail. Because should they fail, the consequences could be catastrophic.

"As NASA's profile changes to more deep space missions, and in particular, deep space human missions, reliability is paramount," said Mr. Richard Russell, NASA Technical Fellow for Materials. "If something goes wrong, there's no safe haven or way to get back home. For deep space, reliability is the key."

After years of study, however, some aspects of COPV behavior remain difficult to understand. "It's a complex stress state that exists between the liner, its overwrap, and the adhesive that holds it together," said Russell. "We need to understand not only the manufacturing process, but material compatibility, and the conditions we put them in. A lot of these questions are difficult to answer."

Today, in many cases, COPVs are blow down systems – their pressure is reduced with use, said Mr. Steven Gentz, NESC Chief Engineer at MSFC. "COPVs used on launch vehicles leave the ground at their highest pressure, and as their contents are depleted, the pressure drops. Their use environment often is measured in minutes," he said. "With going back to the Moon and to Mars, we will have situations where COPVs might sit at a lunar base, or in the Mars Ascent Vehicle, or a lunar orbital platform like Gateway. There will be a long-use environment measured in days, weeks, months, and even years, and we have to get comfortable that they won't leak down or rupture."

The NESC's work on more than 30 COPV-related assessments has focused on test and analysis to help fill in knowledge gaps and help propel the technology forward, with the aim of ensuring their continued safety in future NASA missions.

What Challenges Our Understanding of COPVs?

Designed to hold gases and liquids under pressure, COPVs typically consist of a metal or plastic liner surrounded by a composite overwrap. The liners, made from aluminum, steel, Inconel, elastomers, or plastics, serve as a permeation barrier while the composite overwrap, made from a matrix of fibers in a cured resin material, carries the load generated by its high-pressure contents. Once manufactured, COPVs go through a process called autofrettage, where the tank is subjected to high pressures to compress the inner surfaces, making them less susceptible to operational stresses later.

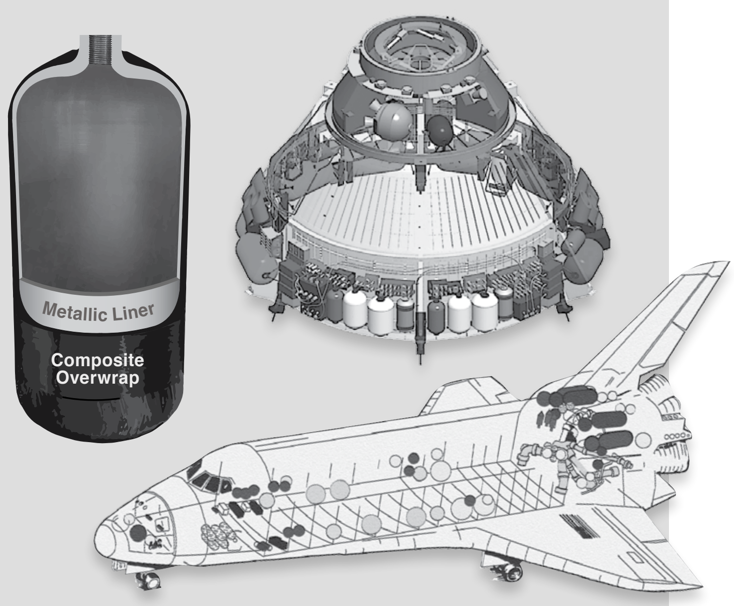
After autofrettage is when many questions begin. Did autofrettage affect the state of stress in the liner? Was there crack growth and will it propagate? Will current inspection methods find those cracks? What is the COPV's tolerance to stress rupture or other failure modes?

Dr. Lorie Grimes-Ledesma at JPL leads the NESC's Composite Pressure Vessel Working Group (CPVWG) and has studied COPVs for nearly two decades, particularly in understanding

NASA History of COPVs

The development and widespread use of COPVs has its roots in a 1970's NASA Firefighter's Breathing System Program, which aimed to reduce the weight and bulk of a firefighter's respiratory protection. Glass composites shaved the weight of conventional steel or aluminum vessels by nearly half and led to their use by municipal fire services and demand for their commercial production.

Fiber technology evolved to stronger overwrap materials such as Kevlar® and carbon. The Space Shuttle orbiter used Kevlar COPVs to store high-pressure helium and nitrogen. Today, the ISS and the the Orion crew module use COPVs in a variety of applications from life support to propulsion.



Illustrations of COPVs on an orbiter and the Orion crew module.

their failure modes. “The complexity of COPVs is deceptive and bleeds into all failure modes associated with these tanks. And there are failure modes we still don’t fully understand,” she said. “The cylinder section of a COPV isn’t all that geometrically complicated, but the mechanics that occur in the dome region are.”

In the dome, the liner tapers, and the way the layers of fiber wind their way over the dome can involve stops and starts and double curvatures. These geometric changes make understanding the stress and strain behavior in the dome difficult. With a three-dimensional state of stress that changes across its structure, COPV failure modes can be difficult to understand or predict. But if it fails, she said, “It will take your spacecraft down. There is so much stored energy.”

Filling in Knowledge Gaps with Tests and Analyses

To help advance COPV technology and be better prepared for long-term space travel, the NESC has been actively engaged in several activities, including a stress rupture test program and reviews of commercial provider and Orion COPVs, said Mr. Michael Kirsch, NESC Deputy Director. “We’ve also worked on the development of state-of-the-art nondestructive evaluation (NDE) techniques, and our COPV working group is actively engaged in the development of design standards for the industry.”

The stress rupture test program began more than a decade ago when concerns arose that COPVs on the Space Shuttle orbiter and the International Space Station (ISS) could be prone to failure of overwrap strands. Although typical industry approaches for stress rupture analysis had been performed prior to flight, shortfalls in the analysis methods and test data were found after a detailed review. Orbiter COPVs were reviewed using existing data, but because ISS and other Agency COPVs would be in use for longer periods of time, the NESC wanted to address some of the shortfalls in stress rupture data and analysis methods.

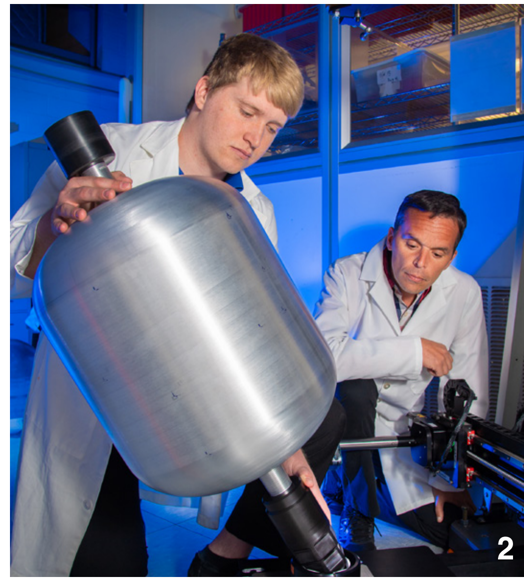
Specialized rigs at the White Sands Test Facility (WSTF) were built to test large quantities of fiber strands at high stress ratios and complex loading scenarios. Over several years, the NESC has collected data to develop a global stress rupture model and new methods of analysis, which have greatly reduced uncertainty in reliability predictions for ISS COPVs.

Cracks in COPV liners can also lead to rupture, and inspecting liners for cracks has become more difficult as COPVs have moved to thinner liners for weight savings, said Dr. William Prosser, NASA Technical Fellow for NDE. “This has been challenging for our NDE techniques to provide the reliable detectability of the maximum flaw sizes they can withstand.” The most commonly used NDE technique has been dye penetrant, which is placed on the liner surface to make cracks visible. “It’s a great technique, but as you get to smaller and smaller crack sizes, they get

The NESC-funded multipurpose pressure vessel scanner enables unprecedented full-surface interior and exterior scans of large pressure vessels. Full probability of detection studies have demonstrated near-surface crack screening capabilities superior to array eddy current and dye penetrant techniques. Far-surface crack detection capabilities permitting crack growth monitoring through all phases of COPV manufacturing. Interior and exterior surface profiles are mapped through low-energy laser-based techniques, with the added benefit of coordinate-mapped high definition imaging.

3D-image profile of lightweight liner

1



2

3

harder to visually see and less distinguishable from the background." And once manufactured, the COPV liner interior is no longer accessible to dye.

Building on laser profilometry and eddy current flaw scanning capabilities developed at WSTF, the NESC began an assessment to design and fabricate a unique, semi-automated COPV liner external and internal inspection system. A method was needed to detect flaws like cracks, buckles, liner thickness variations, and other anomalous changes that can occur after autofrettage. Combining WSTF's capabilities, along with a specialized rotating scanner, probe, and sensors, a 360-degree view of the vessel can now be captured by a data acquisition system. "It can follow the contours on the interior of the vessel," said Mr. Regor Saulsberry, retired WSTF engineer who helped develop the scanner technology. "The sensors look for defects and cracks using the eddy current and laser profilometry maps the interior surface within a few thousandths of an inch. We get a high resolution view of the interior of the tank and end caps that let us see very fine defects."

"Before, we had no way of inspecting to see if autofrettage or proof test cycles caused a crack to grow or how much it grew," added Dr. Prosser. "Other COPV providers are interested in our technique and are pursuing adaptations for their own applications," Dr. Prosser said. "It has had a significant impact." The NESC has also employed NDE techniques like computed tomography to help identify buckled areas between the liner and the overwrap.

Supporting the Commercial Crew Program (CCP) as its partners develop their own COPV designs and explore new use environments has also grown the NESC's COPV knowledge base. "CCP has made us dive into the detailed mechanics of COPVs that we've never needed to pursue in the past," said Dr. Grimes-Ledesma. "But the modeling and analysis capability we've established over the years put us in a good place to support their COPV development."

New designs have considered submerging COPVs in liquid oxygen (LOX) to better manage the temperature requirements of their contents, so the NESC led an assessment to understand how particular carbon fiber composite materials behave in LOX. The NESC investigations to better understand the liner material's capability under service-like conditions resulted in a new approach to analyzing grain size in COPVs.

Another potential hazard COPVs will face on long missions in space is impacts from micrometeoroid and orbital debris (MMOD). For a short time during the Artemis I mission, COPVs located on the interim cryogenic propulsion stage will be vulnerable to MMOD. To understand the failure criteria of these

NESC-Sponsored Research:

1. Tom Delay, retired MSFC engineer, fabricates a series of lined and unlined composite test vessels used to understand the performance of fibers and matrix resins in 2007.

2. Engineers Ayrton Jordan (left) and Anthony Milana at WSTF install a metallic liner into the multipurpose pressure vessel scanner in 2019. Refer to photo on previous page.

3. The "composite" in COPVs refers to a matrix of continuous fibers contained within a resin and wrapped over either a spherical or cylindrical a pressure barrier to form a vessel for gas or liquid containment. Continuous fibers provide tensile strength for structural integrity while the resin carries shear loads in the composite and maintains the fiber position.

4. In 2016, Patricia Howell (LaRC) provided expertise in micro-focus X-ray computed tomography for understanding damage to COPVs from hypervelocity impact tests as part of an NESC investigation into micrometeoroid and orbital debris COPV failure criteria.

5. Robert Browning (left) from WSTF and Curtis Banks from MSFC, install conventional and Fiber Bragg strain gauges on a COPV for testing in 2009.

6. Catastrophic failure of a COPV resulting from a hypervelocity impact test in 2016.

COPVs, an NESC assessment team fired various-sized particles at COPVs and coupons at a WSTF test facility to simulate hypervelocity MMOD impact. "We tested in the COPV barrel and shoulder regions, varied velocity and particle make-up (aluminum and steel), and tested at different impact angles," said Mr. Michael Squire, NESC Principal Engineer. "And we found that the tanks are more robust than originally thought."

Prior risk assessments, based on analysis only, had assumed COPV failure would occur with penetration of the COPV overwrap. After testing, however, the NESC team determined smaller particles could penetrate the overwrap and partially into the liner and the tank would not fail. By more fully understanding the size of particle and depth of penetration required to cause a failure, the risk of failure could be more accurately calculated. "The failure risk for these tanks dropped," Mr. Squire said. "We found when we reran the risk numbers, these tanks were no longer driving the risk for the vehicle."

Keeping tabs on all COPV activities across the Agency, the CPVWG has helped develop COPV standards for NASA and the industry and provided consultation and expertise to answer COPV questions for NASA programs and projects. Their testing and analysis programs have significantly influenced damage tolerance life-test methods, provided data on life expectancy, and the Agency's understanding of crack growth. "The working group is tasked with tracking COPV technology and making sure we understand how COPVs are being used and what gaps might exist in our knowledge of them," Dr. Grimes-Ledesma said. "Because the consequence of COPV rupture is so severe, it has warranted so much work, but because we started working on very difficult and previously neglected areas related to COPV failure modes in 2006 and 2009, the NESC has been in a good position to answer questions to support Orion, commercial crew, and ISS."

COPV Study Has Far-Reaching Benefits

Has the time, energy, and funds the NESC has dedicated to COPVs been worth it? "From an NESC perspective, having the body of knowledge to be able to penetrate the technical issues on the variety of COPVs used by the Agency has been a high return on investment," said Deputy Director Kirsch.

"It's been beneficial for all of our programs," added Mr. Russell. "We want to do more things, travel further, and save weight, so it will always be a challenge. But it is worth the risk if you do it right, take the time, and analyze the risk. It's our job to help engineering organizations inform the risk to people who have to make the big decisions. The NESC role has always been to do these difficult evaluations, tests, and analyses — to help understand the reliability of these complex systems."

Henry A. Rotter, Jr.
Retired NASA Technical Fellow for Environmental Control & Life Support

Apollo to Orion: Building Environmental Control & Life Support for NASA Spacecraft

After 56 years, Mr. Henry (Hank) Rotter, Jr., retired from NASA in late 2019. From the first Moon landing to the development of Orion, his career not only spanned the NASA space program but also contributed to its success. His departure came just as the Agency began to implement plans to return to the Moon in 2024. But before leaving, Mr. Rotter shared a few highlights and lessons learned for his successors, knowing firsthand the challenges that lay before them.

Of all the important things required to send humans safely into space and bring them home again, ego is not one of them. "You need to understand you're not always the smartest guy in the room," said Mr. Hank Rotter. It was a leadership lesson he learned early in his career when he discovered a technician he was working with did not feel comfortable sharing what may have been a better idea for the test they were about to perform. Or when a design mistake could have been avoided simply by talking to someone skilled in brazing. "We're trained across many technical discipline fields, but we're not experts in all of them," he said.

After four decades at NASA, however, Mr. Rotter became the NASA Technical Fellow for Environmental Control & Life Support (ECLS) leading assessments for the NESC on the Space Shuttle, the International Space Station (ISS), and the Orion Program, and assisting the U.S. and British Navies with emergency oxygen supply issues on submarines due to similarity in supplies used on the ISS. The NESC brought him on board in 2003 because of his critical problem solving-skills and vast experience with ECLS systems, which by that time was 40 years deep, its roots going back to the Apollo Program.

Fresh out of college in 1963, the Texas native took a job with NASA's Manned Spacecraft Center, now JSC, ensuring the human centrifuge was ready to train astronauts, testing crew seat designs on the drop tower to limit landing impact loads, and using vacuum chambers to test spacesuit designs to ensure they were tough enough to withstand the harsh conditions of lunar extravehicular activities (EVA). As the mechanical engineer for the centrifuge, Mr. Rotter "crawled all over that thing, which was 20 feet off the ground. And they didn't have safety belts in those days," he said. Mr. Rotter was a test subject as well, taking the centrifuge for a ride before the astronauts began their training. "I took an 11g ride for a few seconds where I weighed a ton and a 4g ride for 4 minutes," he said. "You have to use stomach muscles to breathe because can't use your chest. After that ride, I had to drink some Pepsi just to get enough energy to pick up my sandwich."

It was during centrifuge training that he met astronaut Ed White. "The Apollo 1 fire was very emotional for me. He was the first astronaut to introduce himself to me, and he lost his life in that fire. He was my first hero," said Mr. Rotter, who would take part in every Apollo mission that followed.

While he reveled in the success of Apollo 11, the Apollo 13 mission put all of his technical and problem-solving skills to the test. Walking into the Mission Evaluation Room that day in April 1970, he "knew something bad had happened." He would work the next 18 hours to figure out the best way to transfer water to the lunar excursion module (LEM) for the astronauts. "We laid out all the tubing and connectors on the table that were available in the command module and the LEM," he said.

Photos (from left): Mr. Henry "Hank" Rotter receiving an award from Dr. Robert R. Gilruth, Director of the Manned Spacecraft Center, now Johnson Space Center (JSC), in 1966. Mr. Rotter's NASA identification photo on his first day at the Agency in 1963. Mr. Rotter with astronaut Neil Armstrong at JSC in 2008. Mr. Rotter addressing an NESC Academy class.

"We solved the problem of using square lithium hydroxide cans in the LEM, which had round slots." The experience involved some of the first in-flight maintenance performed for the program. "Afterward, the in-flight maintenance book was the biggest book on board," he said. "We learned more about those two spacecraft in that mission than we'd known before."

The oxygen supply umbilical that Mr. Rotter designed allowed crews of the Apollo 15 and subsequent missions to perform EVAs that would take them 20 feet away from the command module hatch to retrieve film cartridges from the mapping cameras. He also wrote the accompanying procedures on how to handle potential malfunctions and emergencies.

What Apollo taught him transferred well to the Shuttle Program, where he worked for 20 years on ECLS systems, payload integration, and the orbiter tunnel adapter used by crew to access Spacelab, Spacehab, Mir, ISS, and to perform EVAs. On STS-109, a blockage in the coolant system for the orbiter avionics, which were critical for reentry, threatened to bring an early end to the mission. Mr. Rotter and others worked all night to devise a way to protect the system and ensure, even in the worst-case scenario, that the system would get the crew home safely. On board that last successful flight for Columbia was Mission Specialist and Flight Engineer, Dr. Nancy Currie, with whom Mr. Rotter would eventually work on NESC assessments.

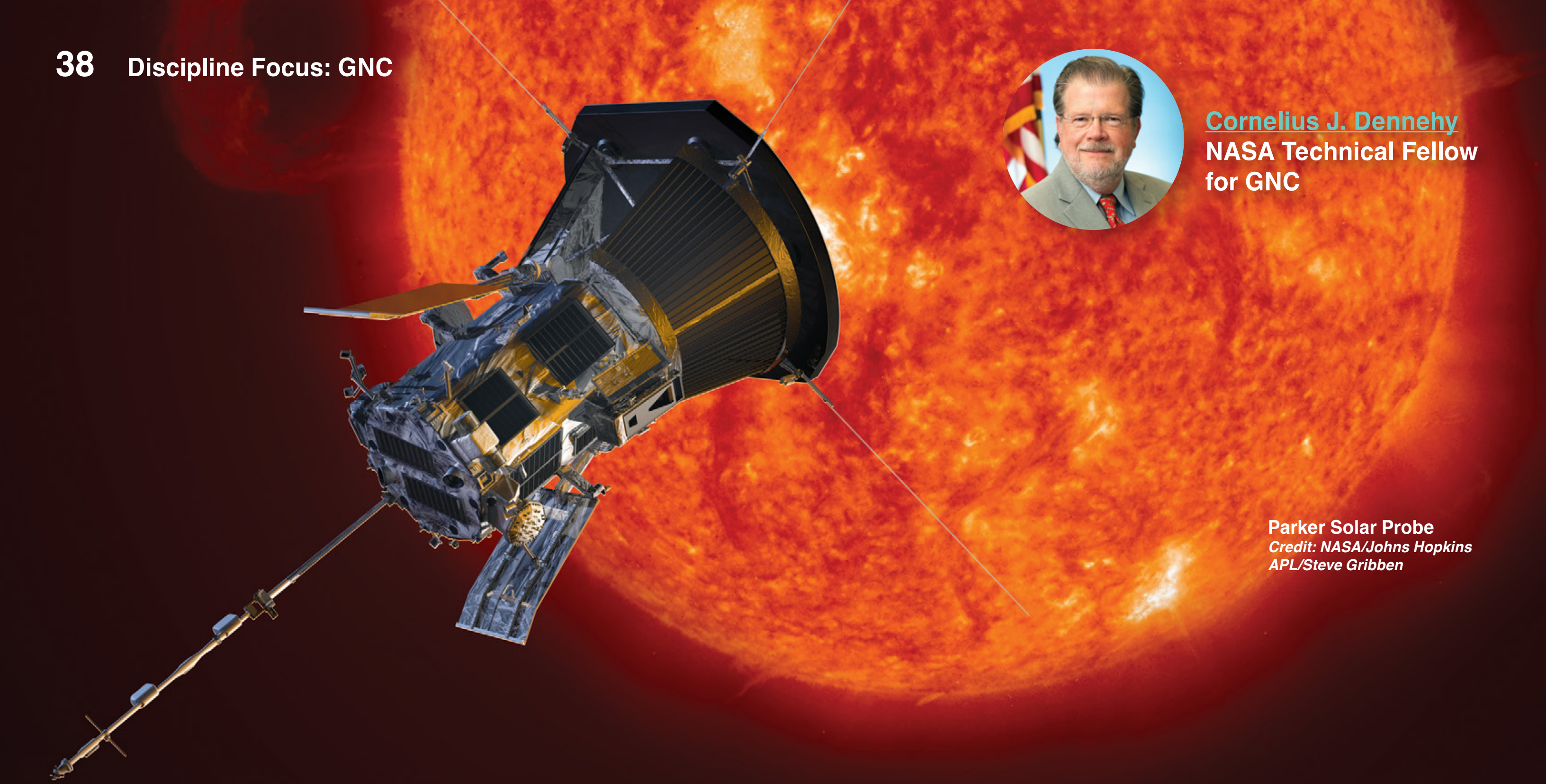
After the 2003 Columbia accident, Mr. Rotter came to work for the NESC. "Solving problems in my days as a subsystem manager and having to find rationale and corrective actions to fly again fit right in with what the NESC was doing."

During his 16-year NESC tenure, he helped the Space Shuttle Program in its return to flight, led teams on investigations into satellite and Mars Science Laboratory issues, and solved challenges for ISS that ranged from addressing heat exchanger and water recovery system anomalies to identifying the cause of water leaking into an astronaut's helmet during an EVA. "I told them a week after it happened where the problem was, but it took a year to prove me right," he said of the formal investigation's conclusion.

With a half century of NASA work behind him, Mr. Rotter has a lot to reminisce about, but he decided there is not much he would change about his career path. "I might have given my family a little more time," he said. "I've told many young engineers that it is hard to balance yourself, your family, and your work. You have to think about all three." He also wishes he would have spoken up on a few things sooner than he did. After the Apollo 1 fire, he found himself in California, reviewing plans for the rebuild of the service module for Apollo 7. He was asked by a manager to present his take. "I was young, nervous, and I'm in front of 100 people saying this is what I think they need to do. The manager actually wanted to hear what I had to say." That boosted his confidence, he said. "The more confidence I got, the more I spoke up."

On September 3rd he officially said goodbye to NASA. "JSC was my extended family. We worked hard and played hard together, and it wasn't unusual to see us running down the hall or running between buildings because we didn't have cell phones then. We were dedicated," he said.

Mr. Rotter left behind a new generation of engineers working on the Artemis Program, which will take astronauts back to the Moon and on to Mars, but he leaves knowing his work at NASA helped chart their course. "I still look up at the Moon every once and a while and think, I helped men to get there."



Parker Solar Probe
Credit: NASA/Johns Hopkins APL/Steve Gribben

Cornelius J. Dennehy
NASA Technical Fellow for GNC

GNC Performance, Verification, and Characterization for Mission Success

The Parker Solar Probe (PSP) began its mission to explore the inner heliosphere with launch in August 2018. PSP will observe the Sun over a series of 24 orbits, reaching a perihelion of 9.86 solar radii (approximately 4.7 million miles). The spacecraft carries instruments to gather data on the particles, solar wind plasma, electric and magnetic fields, solar radio emission, and structures in the Sun's corona. In the extreme environment at distances this close to the Sun, it is of critical importance to maintain attitude within safety constraints (e.g., pointing the thermal protection system to the Sun) to keep spacecraft systems within design limits for temperatures and solar illumination.

The GNC performance, verification, and characterization (PVC) analysis set for the PSP was originally scheduled to have completed by Mission Pre-Environmental Review in September 2017. Due primarily to resource issues, the Project had to slip the schedule for completion of this analysis. The Project began tracking completion of the PVC effort as a risk, and in January of 2018, this was the top risk item. The NASA Science Mission Directorate Chief Engineer and the PSP Program Manager requested NESC GNC assistance to support an independent risk evaluation team with the Johns Hopkins University (JHU) Applied Physics Laboratory (APL) Space Sector Chief Engineer, and an existing tiger team at JHU APL. The independent APL/NESC team, consisting of the NASA Technical Fellow for GNC and NESC GNC Technical Discipline Team members, was chartered to evaluate the scope of the GNC PVC test cases; provide a recommendation for prioritizing the remaining test cases; and assess the residual risk of not having all the test cases completed prior to shipment of the PSP spacecraft to KSC in late March 2018.

The independent team found a large number of test cases (>1000), many of which were driven by the system-level requirement for single-fault tolerance. GNC faults were approximately 10% of the total test cases and were organized into groups. Over half of the GNC faults were eliminated from the GNC PVC simulation cases because they were multiple-fault scenarios (not single-fault) or the outcome could be predicted without having to run a simulation. The remainder were included and analyzed in GNC PVC test set.

Completion of the PVC analyses took longer than expected, and the independent review team remained engaged with the PSP Project on a regular basis, providing interim evaluations of progress and the current risk posture. In addition, the NESC supported key APL reviews: a Testbed Fidelity Review to assess using the PSP hardware-in-the-loop simulator to perform regression tests on a late flight software build that was loaded to the spacecraft prior to launch; and a critical prefueling risk assessment held in July 2018 to ensure it was appropriate to fuel the spacecraft and continue processing for launch.

The review team served a critical function by communicating their independent judgment to decision makers at NASA Headquarters and APL, enabling them to formulate their decisions with information that was as complete as possible. This was a crucial factor in the ability of PSP to work through a number of difficult issues, culminating in a successful launch and two orbits of the Sun in the first full year of successful operation.

For more information, contact Cornelius J. Dennehy | GSFC | cornelius.j.dennehy@nasa.gov

Jon B. Holladay
NASA Technical Fellow for
Systems Engineering

Model-Based Systems Engineering: Informed Decisions for Adoption & Alignment

Since its inception, the Systems Engineering (SE) Technical Discipline Team (TDT) has sponsored numerous efforts to support NASA's SE workforce to better understand how SE can improve our response to develop and deploy NASA missions. One such opportunity, Model-Based SE (MBSE), is to perform SE with digital models, which in addition to better describing the system, also offer the capability to more thoroughly exercise, evaluate, and capture the system performance.

Over the past 4 years, a rich set of lessons learned have informed workforce adoption, laid the groundwork for project infusion, and served as an example for the Agency's evaluation of future digital transformation efforts. Starting in 2016, a cohort of system engineers demonstrated their ability to adopt and apply MBSE to focused areas of NASA missions. The following year, the cohort was expanded, and the number of mission prototypes increased three-fold. Metrics were captured on improvement, model reuse, and ability to integrate and evaluate complex systems. In the past 2 years, roughly a dozen projects have been supported on focused infusion of MBSE via an Agency-level, cross-center, MBSE Community of Practice, and access to a technical peer review team comprising senior SEs and MBSE tooling experts. Both projects and NASA centers have used these assets and lessons learned to continue expanding the scope of MBSE implementation toward more federated and enterprise Agency solutions as resources are available and when the implementation is deemed beneficial.

In partnership with the Office of the Chief Engineer (OCE), the TDT has also piloted the ability for the Agency to move toward an enterprise cloud software solution, validating numerous cost and integration improvements. The OCE has provided access to enterprise-level MBSE software licenses as well as resources for storage and integration of MBSE models, all on a common NASA cloud platform. Focused on workforce improvement, the OCE's Academy of Program/Project and Engineering Leadership (APPEL) has deployed a three-course series on MBSE addressing foundations, applications, and MBSE design and analysis.

From a strategic perspective, the TDT is also out front to help reduce MBSE adoption risk to both workforce and Agency missions. This includes several areas focused on a keen understanding of the community external to the Agency and the longer term future in which MBSE will reside. First, a series of interviews with industry, academia, tool vendors, and other government organizations across the globe was completed and summarized a state of the SE and MBSE discipline across those four communities. This information will further inform the alignment and timing of MBSE infusion, as well as guiding priorities for improvement in tooling, training, and other critical enhancement needs. Second, a competition being implemented through the NASA Tournament Lab provides models of NASA exploration elements. These models, developed external to the Agency, will be used to compare tools, techniques, templates, and approaches from a broader, more diverse community and can potentially be utilized to populate a starter library. Finally, a diverse set of innovative NASA personnel have developed a 20-year long-term vision and road map for NASA's MBSE capability. This vision is an extremely useful tool for describing the landscape of "where the future of MBSE could reside" and help to avoid myopic planning.

With a keen focus on maintaining NASA's rich history of excellence in Systems Engineering & Integration (SE&I), the NESC's SE TDT is informing decisions, both within and outside of the Agency, on when and how to engage digital tooling such as MBSE toward improvement of both SE&I and NASA missions.

The NASA MBSE Community of Practice is a place for like-minded colleagues to share knowledge, promote learning, and develop the tools and practices to bring the benefits of modeling to NASA systems engineers.

nen.nasa.gov/web/mbse
(NASA internal)

NESC ACADEMY'S MOST VIEWED VIDEO IN FY2019

Model-Centric Engineering, Part 1: Intro to Model-Based Systems Engineering

nescacademy.nasa.gov

For more information, contact Jon B. Holladay | GSFC | jon.holladay@nasa.gov

Nonlinear Joint Modeling of Complex Systems Using a Quasi-Static Modal Analysis Approach

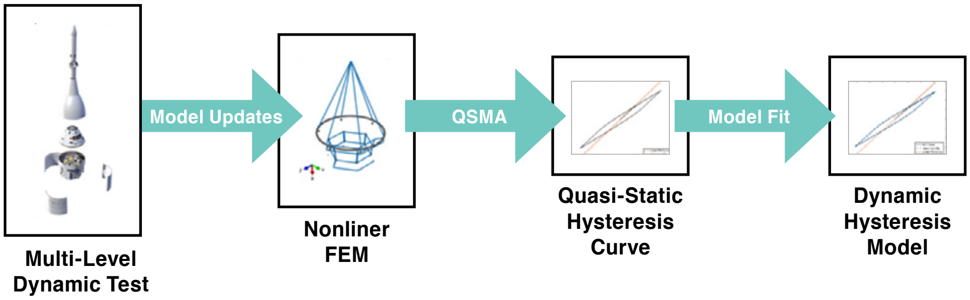


Figure 1: Key steps for construction of uncoupled hysteretic modal equations of motion using a nonlinear FEM.

Bolted structural joints often exhibit load-dependent stiffness and energy dissipation that lead to nonlinear, amplitude-dependent frequency and damping in the structure. As an alternative to direct integration of the nonlinear equations of motion, a quasi-static modal analysis (QSMA) was developed to determine the dependence of frequency and damping on response amplitude using results from nonlinear static analyses. The derivation of QSMA reveals what loading should be applied to a structure such that the resulting static response approximates the dynamic response of the structure over one quarter of a cycle of vibration (or in some cases over a full vibration cycle). The result of the nonlinear static simulation can then be used to infer the way that the structure vibrates in a single mode of vibration over a range of amplitudes. In this context, this methodology develops a process for future model updating (i.e., one can iterate with QSMA much faster than direct transient).

The main steps involved in application of QSMA are summarized in Figure 1. Starting from a multi-level dynamic test configuration, a nonlinear model calibration is performed. The correlated nonlinear finite element model (FEM) in this application was constructed using Abaqus software. Both friction and bilinear elements were used in the model, with joint properties calibrated to match the dynamic test results. Application of the QSMA procedure to the nonlinear FEM previously described yielded quasi-static modal hysteresis curves, which provided effective frequency and damping as functions of modal amplitude. Finally, transient simulations of a QSMA-derived dynamic model were performed by fitting a Bouc-Wen model to the QSMA hysteresis curves. Specifics to each step of the Figure 1 process include:

- **Multi-level dynamic testing** must adequately excite nonlinearities present in the loading envelope, if any exist.
- **Nonlinear FEMs** are expensive to construct, debug, simulate, and correlate. Appropriate selection of nonlinear elements to match the measured response can be challenging.
- **Quasi-static hysteresis curves** require care when derived from commercial FEMs. Since QSMA is not a standard procedure implemented within current finite element analysis codes, it is up to the analyst to ensure correct coordinate transformations are applied during every step of the process: modal extraction, force generation, force application, displacement extraction, and modal filtering. QSMA requires access to the structural mass matrix, which is typically available but can grow quite large for commercial-scale models.
- **Dynamic hysteresis models** transform the numerical QSMA curves of modal force vs. displacement into a single degree of freedom system (i.e., a nonlinear mass-spring model) that includes the hysteresis and which can be integrated in time to obtain the dynamic response.

The results from this process provide expected frequency and damping shifts as a function of response amplitude, but cannot directly provide the response of the nonlinear structure to an arbitrary transient input. Application to a transient dynamic simulation requires the numerical force/displacement results obtained via QSMA to be mapped into an appropriate model form (e.g., Bouc-Wen model).

The key advantages of using QSMA in tandem with a dynamic system model are the decrease in required simulation time – seconds vs. hours – and the physical insight into the nonlinear response that QSMA itself can inform. These advantages can serve to dramatically reduce the cost of model updating efforts and increase the feasibility of uncertainty quantification studies with nonlinear models. In either case, perturbations applied to the FEM can be quickly propagated into a dynamic modal model by running the static load cases required for QSMA and performing an appropriate model fit to obtain uncoupled, nonlinear equations of motion. The main limitations of a QSMA-based approach, as currently conceived, are related to accuracy in the presence of two key assumptions:

- Structural modes remain invariant with load level and are not coupled, and
- a dynamic hysteretic model can be used to represent the hysteresis loop obtained from QSMA.

For more information, contact Joel Sills | JSC | joel.w.sills@nasa.gov

Uncertainty Propagation for Model Validation Using a Hybrid Parametric Variation Method

The Space Launch System (SLS) integrated system consists of a number of components that are assembled into an integrated launch vehicle (LV), Figure 1. Finite element models (FEM) of these components are developed by various contractors and NASA centers, reduced to Hurty/Craig-Bampton (HCB) models, and assembled to represent the flexible body characteristics of the SLS integrated system. Each assembled model represents the SLS integrated system dynamics at a single time in flight, with multiple models being assembled and analyzed to capture the flexible dynamics throughout flight. The assembled models are used for control system stability and performance analysis, coupled loads analysis, and pogo stability analysis.

There is some level of uncertainty in every model, which flows to a level of uncertainty in predicted results. The purpose of uncertainty quantification (UQ) is to provide statistical bounds on prediction accuracy based on model uncertainty. This is distinct from model updating, which attempts to modify models to improve their accuracy. UQ does not improve the accuracy of models, but accepts the fact that the models are inaccurate and attempts to quantify the impact of that inaccuracy on predicted results.

The NESC team developed an alternate technical approach for addressing model uncertainty at the component level and propagating it to system-level results. It is distinct from more commonly used UQ approaches, which are based on varying model parameters. The approach is referred to as the hybrid parametric variation (HPV) method. It combines a parametric variation of the HCB fixed interface modal frequencies with a nonparametric variation (NPV) method that randomly varies the HCB mass and stiffness matrices as Wishart random matrix distributions. The major advantage of the NPV method is that it covers errors in model form, and experience on numerous aerospace programs reveals that almost all errors in FEMs are in form rather than parameter values.

Previous work on UQ for the Mars 2020 powered descent vehicle attitude control found that the NPV method did a better job of capturing uncertainty in the measured transfer functions of the Mars Science Laboratory than parametric methods. In particular, the NPV method introduces a greater degree of uncertainty in mode shape than parametric methods, resulting in matching observed data more closely. However, the NPV method tends to introduce relatively little frequency uncertainty, so it was found that the HPV method, which combines random parametric frequency variations with the NPV method can better “tune” uncertainty at the HCB level to match observed test results.

The HPV method applied to the SLS system anchors uncertainty at the HCB level to component modal test results by categorizing modes into groups and applying differing levels of frequency variation. The specific variations depend on the degree to which a component FEM has been verified through modal testing. The NPV method is then layered on top of the frequency variation to match modal test self- and cross-orthogonality results. The uncertainty is propagated to the system level using a Monte Carlo approach that generates statistics on system-level results. This provides a UQ method that can be traced directly to available test data, and which can be updated as additional data and better correlated models become available. The HPV method can be applied to any result that is based on HCB dynamic models of the system components or the system modal models if uncertainty can be quantified at that level.

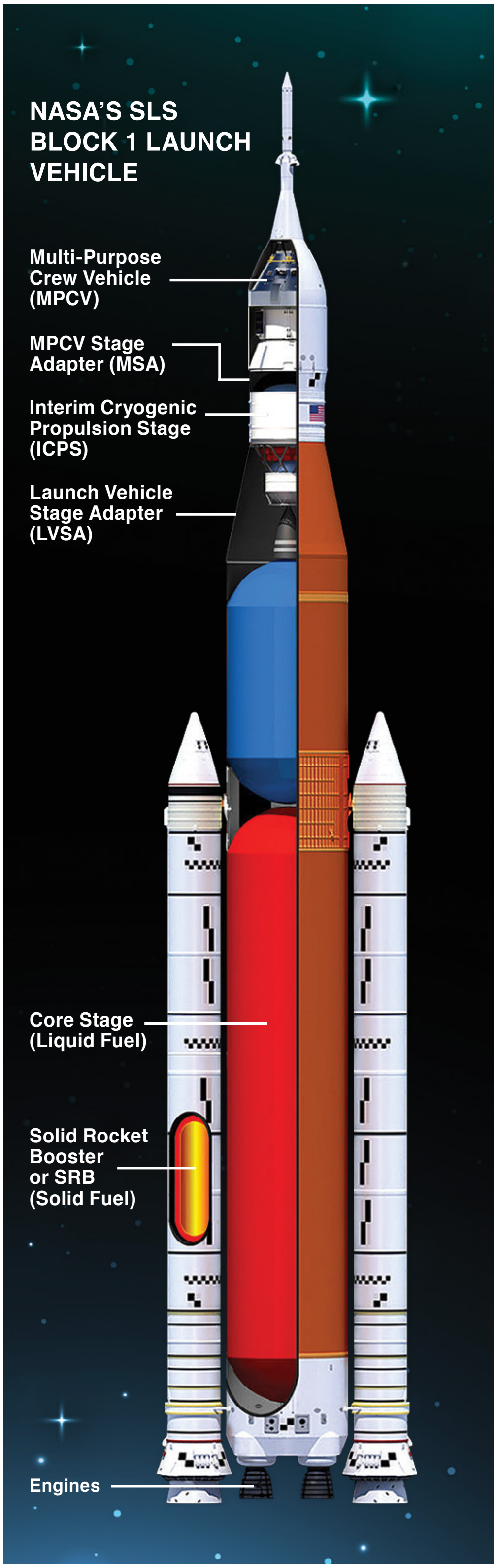
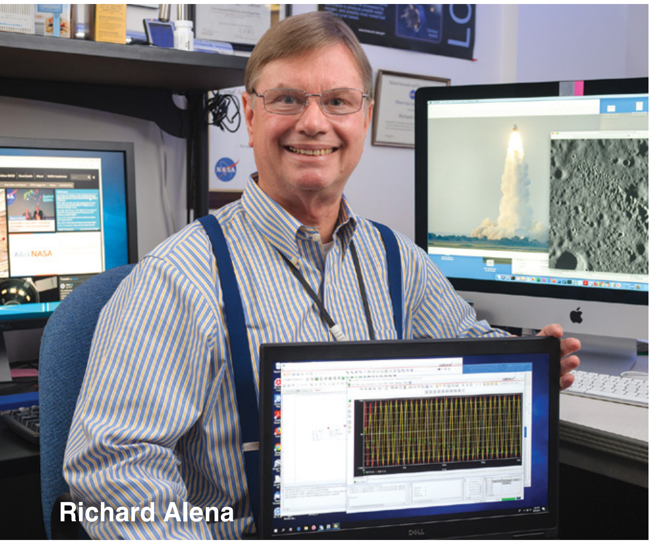


Figure 1. Integrated SLS stacked system.

For more information, contact Joel Sills | JSC | joel.w.sills@nasa.gov

Ames Research Center

The Ames Research Center (ARC) continues to support many critical NESC key activities, leveraging its unique and diverse capabilities including advanced computing and data processing; aerodynamics testing; automation; aerothermal modeling; entry, descent, and landing modeling; testing of advanced thermal protection materials; and human factors research. ARC staff supported major NESC technical assessments and activities in 2019. ARC experts provided significant contributions in areas of data analysis and data mining in support of F/A-18 pilot breathing anomalies. Robotics, automation, and wireless sensor experts are involved in the development of critical technologies needed for deep space missions to the Moon and Mars, where vehicle health monitoring will be an important characteristic of future designs. Ames has representatives on 18 NESC Technical Discipline Teams (TDT), and the Technical Fellow for Human Factors is resident at ARC.


Richard Alena

Applications of Wireless Sensing Systems

A member of the Robotics TDT, Mr. Richard Alena is a computer engineer supporting NESC assessments with his work in wireless sensor technology. His focus is on adding sensors to new and existing space vehicles to measure and assess issues within subsystems and exploring novel ways to send and retrieve sensor data from vehicles already in space.

Recently he has leveraged opportunities with the Technology Education Satellite program at ARC to explore using multiple satellite cluster communications as downlink methods for retrieving data. “Small satellites are an excellent development and demonstration platform for these wireless systems.” Next up for the technology is additive manufacturing. “This holds the promise of embedding sensing systems into materials at the point of manufacturing. The Robotics TDT is also looking at biologically-inspired sensing systems, using nature as a guide in designing future spacecraft systems.” Also, the TDT’s involvement in NESC-sponsored workshops to understand the effects of lunar and Mars dust on human physiology and equipment has opened the door to applying wireless technology to that effort as well.


David Iverson

Data Mining for Pilot Breathing Anomalies

The NESC’s Pilot Breathing Assessment (PBA) to understand pilot physiology in high performance aircraft is amassing huge volumes of data. “We have jets at Armstrong collecting aircraft systems and aircrew breathing data while flying scripted maneuvers,” said Mr. David Iverson, a member of the ARC Data Sciences group.

He joined the PBA analysis team to help manage all of this data. His first job was to time-align and merge the breathing and aircraft data from the initial flights. This allowed the analysis team to detect breathing variations throughout different flight regimes. As the PBA flight count increased, data merging transitioned to AFRC and Mr. Iverson concentrated on isolating specific maneuvers for comparison across flights. Now, when the analysis team discovers unusual patterns in the breathing data, he digs further to help determine possible contributing factors.

He appreciates working with the PBA team, which has pulled together members from across NASA and other government organizations. “It’s great working with a very intelligent team with diverse viewpoints. They get you thinking and keep you motivated. I’ve learned a lot.”

KENNETH R. HAMM, JR.

NESC Chief Engineer

33 ARC employees supported NESC work in FY19

Armstrong Flight Research Center

The Armstrong Flight Research Center (AFRC) provided engineering technical expertise and continued support of numerous NESC activities including instrumentation and fiber optic support for composite overwrapped pressure vessel modeling and the Artemis II spectrometer; development of Agency standards for additive manufacturing; adiabatic demagnetization refrigeration on Stratospheric Observatory for Infrared Astronomy science instruments; and support of efforts to help the U.S. Navy and Air Force better understand the reason for physiological episodes in their fighter aircraft fleet. AFRC has been instrumental in the NESC's flight test campaign to gather missing information regarding pilot breathing to help shed light on the human-machine interaction during high-performance flight.


Mark Kraus, Phillip Wellner, Ronald Shepherd

Tracking Pilot Breathing in Flight

Mr. Phillip Wellner is the lead life support engineering technician for the NESC Pilot Breathing Assessment (PBA) to address physiological episodes in fighter aircraft. He, along with Mr. Ronald Shepherd and Mr. Mark Kraus, take care of the pilots and the life support equipment used during flight to measure pulse, breathing rates and rhythm, lung capacity, inhalation and exhalation, as well as the rate and purity of the air coming in and out of the pilot's mask. For the PBA they have also integrated sensors with the life support gear to measure oxygen use during flight and are uploading the data for study.

They also assist the pilot just before flight. "We're paying close attention to how equipment is fitted to the pilot, if seals are good, and equipment is seated correctly," said Wellner. "Coming from the Air Force, I saw similar incidences during my own career, and now I'm at NASA to figure out why it's happening. What we're doing is really helping the fighter pilot community avoid these episodes. I think some really good things will come out of this."


Jack Ly

Understanding the Pilot/System Interface

An operations engineer at AFRC, Mr. Jack Ly is working on the NESC's PBA, which is helping the U.S. Navy address physiological episodes across their F/A-18 fleet. The assessment team is collecting data on pilot respiratory rates, tidal volumes, and air composition to better understand the pilot/system interface.

Mr. Ly's work includes ensuring aircraft airworthiness, maintenance completion, and aircraft instrumentation operability. On the day of testing, he makes certain all assets involved – from pilots, researchers, and control room personnel to range assets, flight schedules, and equipment – are coordinated and ready to go.

He has enjoyed working on a unique, human factors-related issue with a NASA-wide focus. "Because the problem is so complicated, we had experts from every Center helping out, and it was a good project in terms of leveraging NASA's assets to solve a national problem. Personally, I am new to Armstrong and running this project gives me visibility into our operations here. It has also given me a lot of learning opportunities and helped to fast track my growth in operations engineering."

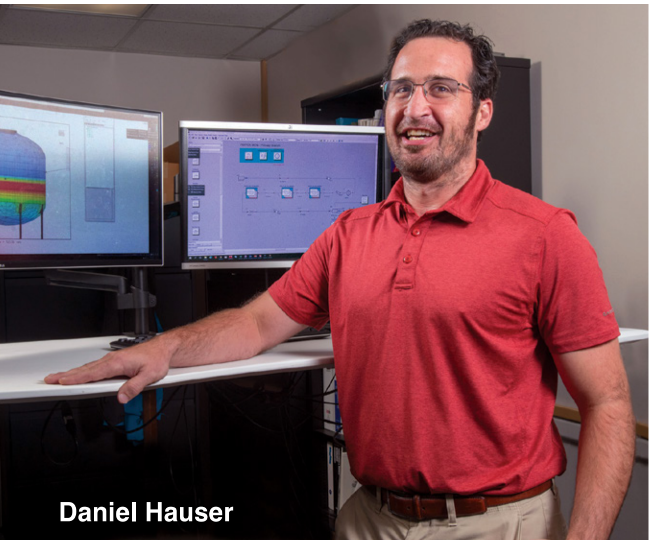
DR. W. LANCE RICHARDS

NESC Chief Engineer

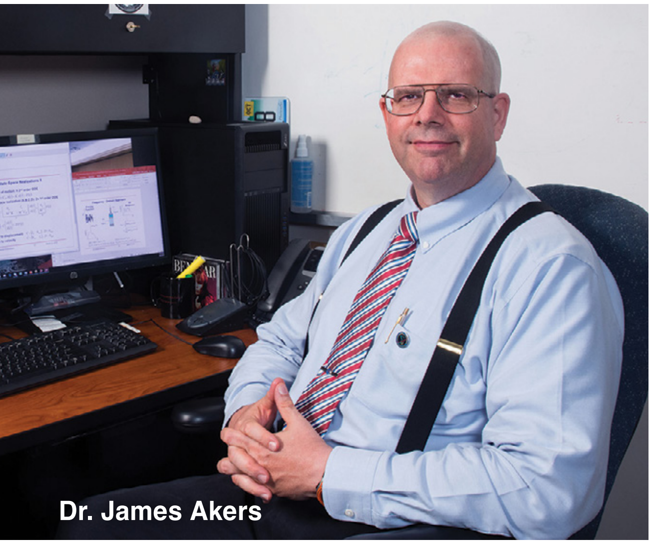
43 AFRC employees supported NESC work in FY19

Glenn Research Center

The Glenn Research Center (GRC) provided a broad spectrum of technical expertise in support of 20 NESC assessments/activities and 18 NESC Technical Discipline Teams (TDT). These activities supported all mission directorates as well as several cross-cutting discipline efforts. Significant GRC contributions this year were in support of understanding the complex loads placed on the integrated Orion Multi-Purpose Crew Vehicle (MPCV) and Space Launch System (SLS) vehicles, as well as fluid system analyses. The NASA Technical Fellows for Cryogenics and Loads & Dynamics, as well as deputies for the Propulsion, Electrical Power, Systems Engineering, and Nuclear Power & Propulsion TDTs, are resident at GRC.



Daniel Hauser



Dr. James Akers

ROBERT S. JANKOVSKY

NESC Chief Engineer

66 GRC employees supported NESC work in FY19

Fluid Systems Modeling

When the Robotic Refueling Mission 3 experiment that flew to the International Space Station in December 2018 experienced valve issues during ground tests to transfer cryogenic methane between tanks, the NESC called on Mr. Daniel Hauser's expertise in cryogenic model development to help solve the problem. As the modeling lead for the NASA cryogenic group, he understands the challenges that come with transferring cryogenic propellant in zero-g. "I built fluid models to help the NESC characterize the system and allow predictions for ground and on-orbit testing."

He also assisted the NESC in building fluid dynamics models of the pressurization system for the Orion European Service Module after it experienced valve issues during system testing. "I was able to give some predictions of valve performance and match issues they were having on the flight hardware for the Artemis I mission." The work provided Mr. Hauser the opportunity to not only gain technical knowledge from assessment team members, but "non-technical knowledge as well," he said, "like organization and communication."

Transferring Knowledge to the Next Generation

With expertise in modal testing, signal processing, statistics, and probability, Dr. James Akers recently assisted the NESC in understanding the complex loads placed on the integrated Orion MPCV and SLS vehicles during their roll out to the pad and subsequent launch. He has supported modal test planning for the integrated vehicle, the mobile launcher, and SLS core stage, as well as supported the Orion MPCV Mass Simulator design, build, and modal test planning. "The NESC is such a vital contributor to NASA. I enjoy the opportunity to work with top notch people from academia, the government, and industry on highly technical projects, and I enjoy communicating my results and spreading that knowledge," he said.

A strong advocate of mentoring, Dr. Akers also supports the NESC Structures, Loads, and Mechanical Systems early career community, sharing what he has learned with the next generation. "With people retiring combined with not having the natural mentoring we have had in the past, knowledge transfer is critical to keeping technical expertise from evaporating within the Agency."

Goddard Space Flight Center

The Goddard Space Flight Center (GSFC) continued a broad range of support to NESC activities, including 30 assessments and 19 Technical Discipline Teams (TDT). GSFC is the resident Center for the NASA Technical Fellows for Systems Engineering, Mechanical Systems, and Guidance, Navigation, & Control. Contributions included support of the southern hemisphere meteoroid environment measurements; aerodynamic buffet flight test; assessment of electrical, electronic, and electromechanical parts copper wire bonds; International Space Station remote power control module hot mate/demate during extravehicular activity; flight mechanics analysis tools interoperability and component sharing; and the creation of Agency standards for additive manufacturing.


Andrew Glendening


Tamra Goldstein


Dr. Meng Chiao

FERNANDO A. PELLERANO

NESC Chief Engineer

85 GSFC employees supported NESC work in FY19

A NASA Standard for Additive Manufacturing

Mr. Andrew Glendening is working with approximately 25 metallurgists and materials engineers from across nine centers to develop a NASA standard for additive manufacturing (AM). "We are writing the Agency documents and the standard for AM metals and polymers, outlining all top-level requirements the projects will need to ensure they get a quality part for their flight program." The team is leveraging an AM standard developed by MSFC. "We are taking what Marshall did, which was written with their programs and developers in mind for one specific AM technology, and expanding it to apply to AM across the Agency for most metal AM systems and the most common polymer systems." Mr. Glendening is providing his metallurgy expertise and experience in writing and verifying requirements to the assessment. "I have really enjoyed working with people from all over the Agency. We all have similar technical backgrounds but highly diverse programmatic backgrounds." He has also worked on previous NESC assessments involving environmental corrosion and bearing ball testing.

Fostering the Software Engineering Discipline

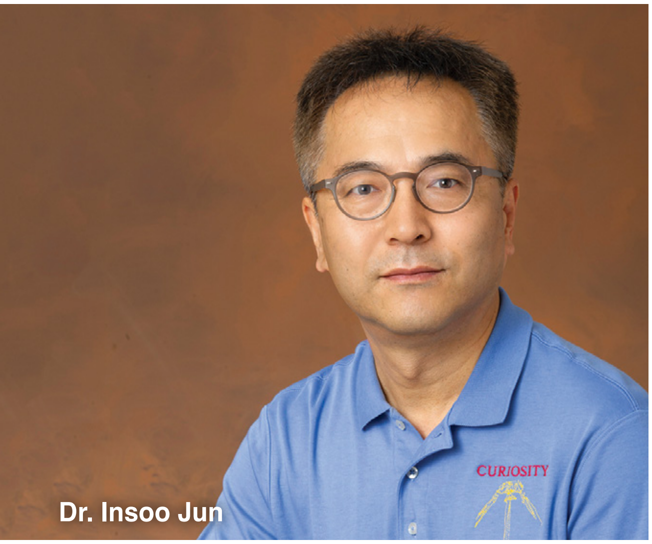
Ms. Tamra Goldstein is a member of the Software TDT and is the GSFC point of contact for the Center's implementation of NASA software engineering requirements. Her work involves extensive collaboration and outreach to ensure guidelines on software development and execution are followed for NASA missions. She also cultivates a software engineering community of practice and is helping further the discipline at GSFC, across NASA, and the extended community. "I also work cooperatively with my peers at other centers, and a big part of that is sharing experiences and lessons learned," she said. "I enjoy meeting with the folks who are engineering the software and understanding all the ways software is playing an integral role in everything we do." From laptops to augmented reality environments, Ms. Goldstein said she gets to observe firsthand how the technology is directly supporting NASA missions.

Collaborating Internationally via MBSE

A member of the GSFC Instrument and Payload Systems Engineering branch, Dr. Meng Chiao, together with the X-ray Imaging and Spectroscopy Mission (XRISM) Resolve instrument team, are building a soft X-ray spectrometer to study clusters of galaxies. The mission is a collaboration between NASA and the Japan Aerospace Exploration Agency (JAXA). The satellite will go to low-Earth orbit to detect soft X-ray photons (0.3–12 keV) with the objective of understanding the dynamics, evolution, and abundances in the universe. Through collaboration with the NESC Systems Engineering TDT Model-Based Systems Engineering (MBSE) Infusion and Modernization Initiative and GSFC's Security Engineering Team, XRISM/Resolve instrument systems engineer team members from JAXA and NASA are managing requirements together using an MBSE software tool, utilizing model products for project reviews, and moving toward a cloud-based real-time collaborative environment.

Jet Propulsion Laboratory

The Jet Propulsion Laboratory (JPL) supported 30 NESC assessments and 19 Technical Discipline Teams (TDT) in FY19. Activities included technical leadership of the Composite Pressure Vessel Working Group and the Avionics Telecommunications Community of Practice, engineering in support of the flexible body dynamics modeling, low-jitter space observatory attitude-control analysis, Rad750 qualification, and quantifying reliable methods for managing mass growth. In addition, JPL designed an in-mask CO_2 and water vapor sensor in support of the F/A-18 Pilot Breathing Assessment and delivered a data acquisition unit to the Super Pressure Balloon Program. JPL's expertise in mission design and navigation, parachutes, and entry, descent, and landing systems assisted NASA's Commercial Crew and Artemis Programs in support of their upcoming missions. JPL assisted in the advancement of Agency engineering initiatives and standards. The NESC Chief Scientist and the TDT deputies for Space Environments and Guidance, Navigation, & Control also reside at JPL.



Dr. Insoo Jun

Mitigating the Risks of Space Radiation

Reducing space radiation risk to human crews and equipment requires a robust space environment-monitoring and forecasting architecture that will support NASA's plans for deep space exploration. As the Space Environments TDT Deputy with expertise in space environments for the outer planets, Dr. Insoo Jun is assisting the NESC in evaluating options for this architecture. His role is to ensure the study includes consideration for augmenting lunar-based space weather infrastructure to support Mars missions.

While Dr. Jun studies all aspects of the space environment, including micrometeoroid and orbital debris, plasma, and planetary atmosphere, his specialty is high energy radiation. His work at JPL has included using the Mars Curiosity Rover to better understand the planet's neutron environment. "While I tend to focus on JPL flight projects, the NESC has given me an opportunity to look at broader NASA activities and more opportunity to contribute my expertise to the success of NASA missions. I can work with Centers I don't typically work with like Langley and Marshall. It's giving me a wider perspective on what NASA does."


Dr. Daniel Winterhalter

Researching the Dust Threat to Future Moon and Mars Missions

Since joining the NESC as its Chief Scientist in 2004, Dr. Daniel Winterhalter has organized workshops to study the effects that dust, both lunar and Martian, will have on humans and machinery. "The dust particles look like sharp needles and can enter the lungs. And equipment like space suits and habitat doors will be affected dramatically."

The workshops have brought together experts from NASA, industry, and the medical community to share science and engineering data to formulate a program to mitigate the threat. His NESC work has also included study of the composition and depth of lakes on Saturn's moon Titan and advancing wireless technology for NASA missions.

Dr. Winterhalter will retire this year after 41 years as a research scientist at JPL. He said the NESC provided him insights into diverse areas of engineering and new perspectives on problem solving. "I've enjoyed the camaraderie, their capability, and their willingness to look at other approaches and break down traditional stove pipes to get something done. I can't believe how lucky I've been to be part of the NESC."

KIMBERLY A. SIMPSON

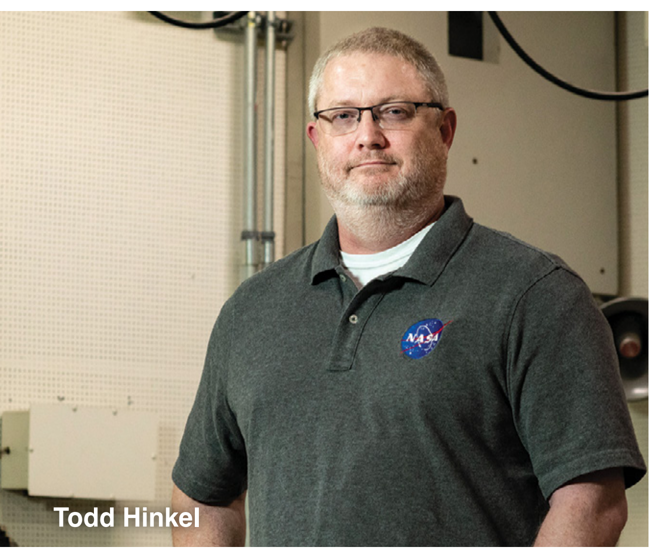
NESC Chief Engineer

65 JPL employees supported NESC work in FY19

Johnson Space Center

The Johnson Space Center (JSC) and the White Sands Test Facility provided engineering analysis, design, and test expertise for the continuous operation of the International Space Station (ISS), development of the Orion Multi-Purpose Crew Vehicle and the Space Launch System (SLS), and consultation for Commercial Crew Program (CCP) vehicles. JSC personnel provided expertise and leadership to numerous assessments within the Agency relating to ISS remote power control module hot mate/demate risk to the extravehicular activity crew; SLS loads and dynamics; Orion transportation loads on the Super Guppy aircraft; composite overwrapped pressure vessels; and pilot breathing in high performance aircraft. NASA Technical Fellows who reside at JSC (Passive Thermal and Structures) joined with other Agency discipline leaders to strengthen technical community connections through joint sponsorship and participation in activities such as the Structures, Loads, and Mechanical Systems Young Professionals Forum and the Thermal and Fluids Analysis Workshop.

Dr. William Walker



Todd Hinkel

T. SCOTT WEST

NESC Chief Engineer

75 JSC employees supported NESC work in FY19

Understanding Thermal Runaway to Inform Battery Design

Two years ago, Dr. William Walker assisted the NESC in developing a small-format calorimeter designed to measure the total energy yield from a lithium-ion battery thermal runaway event. What made this especially challenging is that the design also had to measure how the energy left the runaway cell by determining the fraction conducted into the cell casing versus the fraction vented. “We gained a lot of beneficial information from the small-format calorimeter, and it has supported a number of programs including Orion, CCP, Exploration Extravehicular Mobility Units, and ISS,” he said. Today he is working as the deputy assessment lead on the next generation of that technology, a calorimeter for large format cells greater than 100 amp hours.

“This design addresses unique challenges associated with larger cells which have considerably higher thermal runaway energy release. There are significant challenges in developing an infrastructure to extract all of the heat and ejecta particulate before anything can make its way out of the calorimeter,” he said. “We are running experiments and processing data to develop a full characterization of thermal runaway behavior and determining how much energy remains in the cell casing that could directly conduct to neighboring cells. We’ve built on lessons learned from the small format calorimeter, but this is a completely different approach altogether.”

Building Parachute Reefing Line Cutter Hardware

During reentry, Orion’s drogue and main parachutes are reefed to allow a phased opening of the chutes. “This controls loads on the chutes and the vehicle,” said Mr. Todd Hinkel. As the Technical Discipline Lead for JSC pyrotechnic systems, he is part of a JSC/NESC team that is building reefing line cutters that fire at timed intervals to allow parachutes to open. “Because pyrotechnics is a niche discipline, there are limited outside sources for these cutters,” he said. “By capturing that expertise in house and expanding our core knowledge, it will give the Orion Program as well as NASA’s CCP partners an alternative source option for this equipment.” The NESC has assisted the effort by providing experience in parachute environments. “With parachute deployment there is a lot of dynamic activity going on with shock and vibration loads. The NESC is helping us define those dynamic environments, which we will need to qualify these devices. It’s good to bring in outside eyes to the team.”

Kennedy Space Center

The Kennedy Space Center (KSC) provided technical expertise to 27 NESC activities and Technical Discipline Teams in 2019. KSC personnel were engaged in numerous NESC assessments including: Commercial Crew Program (CCP) crew module ascent cover modeling; Space Launch System (SLS) propellant pressurization modeling; International Space Station (ISS) electrical connector hazard evaluation; heatshield thermal instrumentation evaluation; and NASA additive manufacturing standard development. Likewise, the NESC provided technical support for programs at KSC including: CCP composite overwrapped pressure vessel analysis; Exploration Ground Systems crew module recovery sea condition dynamics; Crew Module Test Article design evaluation; and Mobile Launcher modal test analysis. The NASA Technical Fellows for Electrical Power and Materials reside at KSC and rely on KSC expertise in many of their activities. The NESC also invested in KSC's Applied Physics Laboratory to evaluate heatshield instrumentation and flight propellant tank quantity measurement techniques.

Hong Salas


Kelli Maloney

STEPHEN A. MINUTE

NESC Chief Engineer

37 KSC employees supported NESC work in FY19

Tapping into NASA-Wide Expertise

As an electrical engineer, Ms. Hong Salas is adept at reviewing the electrical and computer systems of NASA's CCP partners to ensure they meet requirements and are functioning as designed. That experience proved invaluable to the NESC's recent assessment of a commercial partner's Autonomous Flight Termination System (AFTS).

She supported the team's efforts to understand the complexities of the AFTS circuitry and enjoyed the opportunity to dive a bit deeper into a system than her work typically calls for. "While it fit in to what I do, it was very challenging and helped me learn a lot more about the system."

Working with a NASA-wide team of experts, she also broadened her KSC perspective. "This assessment taught me a lot. I could ask questions, and they were there to answer. It opened my mind and helped me to become a better engineer, too," she said. "Ms. Salas' capable and diligent efforts on our joint activities have enabled success," added Dr. Christopher Iannello, NASA Technical Fellow for Electrical Power. "I look forward to future collaborations."

Mitigating Hazards in Ground Systems

As the lead ground engineer for the CCP, Ms. Kelli Maloney ensures hazard mitigations are in place and functioning as they should for the equipment and systems used by NASA's CCP partners. Having worked as a design engineer for SLS structural components such as the crew access arm and its umbilicals, she is very familiar with the potential hazards that come with the development of new spacecraft systems. Ms. Maloney draws on that experience when reviewing designs and conducting tests, focusing directly on the safety of the crew and their mission.

Her expertise was critical during an NESC assessment of a CCP provider's new approach to loading cryo-propellant after the onboarding of crew, a departure from NASA's traditional crew ingress after propellant has been loaded. "We went through the schematics component by component to understand the systems, identify any gaps, and assess its rigor," she said. "It was an independent look with system experts from the NESC. Some aspects were similar to Shuttle and the NESC's familiarity with Shuttle systems provided valuable help."

Langley Research Center

The Langley Research Center (LaRC) personnel continued to support an extensive range of NESC assessments for the Commercial Crew Program (CCP), Exploration Systems Development, the Science Mission Directorate, and the Department of Defense. Independent modeling and simulation of mission trajectories were performed for the Orion Multi-Purpose Crew Vehicle/Space Launch System and the CCP providers. LaRC personnel were also engaged in testing and analysis of parachute landing systems and composite overwrapped pressure vessel components in CCP providers' spacecraft. LaRC personnel continued to lead an investigation into physiological issues associated with pilot breathing when operating high-performance aircraft like the F/A-18 and F-15 used by the U.S. Air Force, U.S. Navy, and NASA. The NASA Technical Fellows for Aerosciences, Avionics, Flight Mechanics, Nondestructive Evaluation, Sensors & Instrumentation, and Software are resident at LaRC. Ms. Mary Beth Wusk now serves as NESC Chief Engineer.


Kellie Kennedy


Dr. Scott Striepe

MARY BETH WUSK

NESC Chief Engineer

213 LaRC employees supported NESC work in FY19

Exploring Pilot Breathing During High-Performance Aircraft Operation

Ms. Kellie Kennedy's expertise in human factors and her research on the psychophysiological effects of hypoxia has been an asset to recent NESC assessments exploring pilot breathing during jet aircraft operation. She worked with the NESC team on an independent review of the Navy's efforts to address an increased occurrence of physiological episodes across their F/A-18 fleet. Ms. Kennedy traveled to several F/A-18 locations including onboard the USS Eisenhower to observe flight operations and interview pilots, maintainers, and medical professionals. Her work identified a need for increased human system integration including understanding human breathing in the aircraft operational environment. She now serves as a member of the NESC Pilot Breathing Assessment to explore this knowledge gap.

"The increasing complexity of the modern flight deck equates to greater cognitive demand for the pilot. Examining pilot needs ensures we are sufficiently meeting these needs with the vehicle," she said. "This has been an incredible learning experience to participate in a major multi-center flight study. I've never felt more valued, effective, and inspired to do good than I have working with the NESC."

Modeling the EDL Phase of Spaceflight

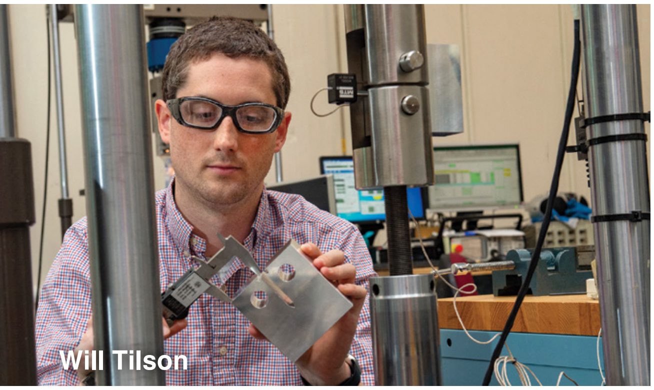
Dr. Scott Striepe is supporting an NESC assessment in collaboration with the CCP to develop independent modeling and simulation capabilities of NASA's CCP partners' entry, descent, and landing (EDL) flight phases. Because EDL presents a high-risk element in space travel, the simulations provide technical insight and give NASA the ability to work with the CCP partners to identify and resolve vehicle flight issues. As the Dragon 2 subteam lead, Dr. Striepe and his team are focused on ensuring the Dragon 2 is ready to fly the EDL phase with crew aboard. "SpaceX provides us information about their system, and we create simulations to confirm the system is operating as described and if there are any areas that require additional analysis."

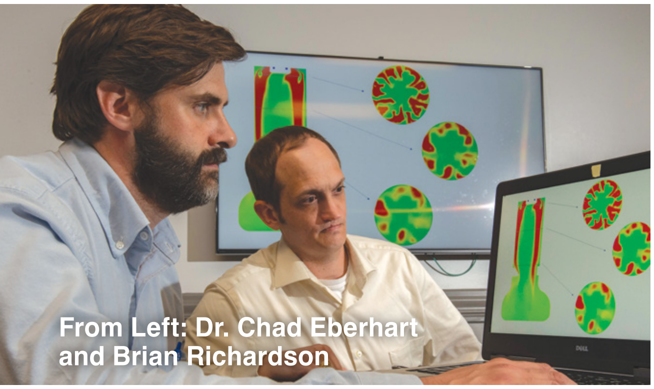
Dr. Striepe has been involved in previous NESC assessments and appreciates how the organization is matrixed across Centers and across the country. "We can interact with expertise without the boundaries I saw when I first started at Langley. It's very powerful and necessary within NASA to make sure our missions are successful."

Marshall Space Flight Center

The Marshall Space Flight Center (MSFC) provided engineer, scientist, and technician subject matter expert (SME) support to over 49 NESC activities. These activities involved exploration systems development, space operations and environmental effects, science, and crosscutting discipline activities. Some of the more significant efforts included composite shell buckling, additive manufacturing, model-based systems engineering, high-temperature insulations, advanced chemical propulsion, modeling and simulation of launch vehicle/spacecraft interfaces, and human factors task analyses. The NASA Technical Fellows for Propulsion, Space Environments, and Systems Engineering, and the Technical Discipline Team Deputies for the Human Factors, Nondestructive Evaluation, Propulsion, Nuclear Power and Propulsion, Software, and Space Environments are resident at MSFC.


From Left: Jason Vaughn, Dr. Erin Hayward, and Todd Schneider


Will Tilson


From Left: Dr. Chad Eberhart and Brian Richardson


STEVEN J. GENTZ

NESC Chief Engineer

134 MSFC employees supported NESC work in FY19

ISS RPCM Hot Mate/Demate Assessment

Mr. Todd Schneider led a team supporting an NESC assessment on International Space Station (ISS) extravehicular activity (EVA) safety. The team from the Nonmetallic Materials & Space Environmental Effects Branch included Mr. Jason Vaughn and Dr. Erin Hayward, considered plasma and spacecraft charging SMEs. This assessment investigated hazards that might occur if an astronaut attempted to remove or replace a remote power control module (RPCM) while the circuit was powered. The MSFC team focused on creating high-energy discharges in a vacuum chamber that included a background plasma comparable to the ISS environment. The discharges yielded fast-moving molten metal particles and merited safety concerns for compromising space suit materials. The team contributed laboratory data and analyses from more than 50 tests to characterize specific threats to EVA suit materials and astronaut safety.

CCP COPV Liner Assessment

While with the Materials Analysis & Test Division, Mr. Will Tilson supported an NESC investigation into Commercial Crew Program (CCP) composite overwrapped pressure vessel (COPV) liners by conducting imminent failure-simulated service testing and developing a single-cycle crack initiation test. During these activities, he developed test grip alignment procedures to avoid specimen buckling, test control methods to simulate service life loadings, and analysis tools to rapidly communicate test results. When initial results indicated potential certification issues, he developed novel test procedures to evaluate crack formation during proof loadings. He developed a validation technique for high resolution digital image correlation used to detect material strain localizations. He worked with an Agency-wide team resulting in guidance on risk levels and advancements in COPV certification.

Engine Gas Generator Baffle Assessment

Mr. Brian Richardson and Dr. Chad Eberhart are members of the Propulsion Systems Fluid Dynamics Branch. Mr. Richardson has worked on a variety of engineering applications including valves, turbomachinery, injectors, and combustion modeling for the Space Shuttle, Space Launch System, and CCP. Dr. Eberhart's work has supported test and analysis of unsteady flows, with a focus on evaluations of liquid rocket combustion dynamics through high-speed data analysis and modeling. Mr. Richardson supported the NESC by conducting chemically-reacting, time-accurate, three-dimensional computational fluid dynamics analysis of an engine gas generator (GG), while Dr. Eberhart's support involved computational acoustics model development and analysis. Their combined efforts required simulation tool and analysis advancements that provided new understanding of the unsteady flow, thermal, and acoustic environment inside the GG. These characteristics were evaluated for different GG baffle designs, and results were provided as guidance to the CCP for benefit to NASA's human-rated spaceflight programs.

Stennis Space Center

Expert technical support was provided to the NESC by the Stennis Space Center (SSC), including subject matter expertise in hardware testing, facility capabilities, risk assessment, test operations, modeling, and space exploration. Even with a smaller number of employees than other centers, SSC supplied technical expertise in several NESC assessments including human factors' effects and fatigue prevention during prolonged testing operations, O-ring material obsolescence for critical aerospace applications, hydrogen and oxygen pressurization systems' modeling for the Space Launch System, and a Commercial Crew Program (CCP) partner mishap investigation. SSC took advantage of the unique opportunity for collaboration and networking by supplying three experts as new NESC Technical Discipline Team (TDT) members in the Structures, Cryogenics, and Aerosciences TDTs. SSC enabled the open exchange of ideas and collaborative decision making by utilizing its unique locale, transportation capabilities, and cost effectiveness by hosting the NESC Joint Data Connectivity TDT face-to-face meeting.

Tom Jacks

David Coote

MICHAEL D. SMILES

NESC Chief Engineer

15 SSC employees supported NESC work in FY19

Fostering Collaboration Across Centers

Mr. Tom Jacks has been a member of the Mechanical Systems TDT for more than a decade. As the Deputy Chief of the Mechanical Engineering Branch for the SSC Engineering and Test Directorate, the TDT provides him with a unique technical resource. "It is a great collaborative environment that the NESC fosters with these TDT teams. We tend to focus on the work the TDTs do themselves, but there is this ancillary benefit that doesn't get talked about as much."

At recent TDT face-to-face meetings, he met people knowledgeable in oxygen compatibility that directly benefited work he was doing at SSC and toured a SpaceX facility that prepared him for upcoming hardware testing for that CCP partner. He has also brought TDT members to SSC so they stay informed on the Center's test facilities and capabilities. It is these types of interactions that he said pay dividends. "We can develop contacts throughout the Agency that we can go to with a problem or question and find the answers we need."

TDTs - A Ready Source of Expertise

Mr. David Coote, Deputy Chief Engineer of SSC, is a member of the Propulsion, Cryogenics, and Nuclear Power & Propulsion TDTs. Working at NASA's largest launch vehicle engine test facility, he said the three disciplines often overlap and share many of the same members.

Through his TDT work, he has lead an NESC assessment to quantify overpressure risk in SSC engine test facilities, supported the Cryogenics Technical Fellow to develop a road map for future cryogenics development at NASA, and has researched novel engine exhaust capture systems and ground test options for a nuclear thermal propulsion engine for deep space exploration.

"Because TDTs work collaboratively, we get familiar with each other and when problems arise, we are a ready available source and asset to identify the right people with the right expertise," he said. "Having a TDT allows you to delineate the work based on each center's unique expertise. There's a benefit to integrating the technical discipline to be more responsive to issues as they arise."

From left - First row: Richard Schwartz (LaRC); Robert Navarro (AFRC); Reggie Kidd (Analytical Mechanics Associates); John Albright (JSC); James Burns (University of Virginia); Timmy Wilson (NESC Director); Second row: Elham Maghsoudi (JPL); Kylene Kramer (Analytical Mechanics Associates); Eric Binter (U.S. Army); Charles Moore (KSC); Barry Wilmore (NESC Chief Astronaut); Sandy Riley (Alutiiq Commercial Enterprises); Third row: Thomas Evans (Millennium Engineering & Integration, Inc.); Amri Hernandez-Pellerano (GSFC); Pavel Babuska (Aerospace Corporation); William Leser (LaRC); David Soto (KeyLogic); Michael Kirsch (NESC Deputy Director); Fourth row: Andrew Doan (Quartus Engineering); Phillip Wellner (AFRC); Karl Heiman (JSC); Brent Erickson (Quartus Engineering); Kristopher McDougal (MSFC); Fifth row: Thomas Horvath (LaRC); Not pictured: Paul Blelloch (ATA Engineering, Inc.); Anthony Carden (Jacob's Technology, Inc.); Kevin Hall (U.S. Air Force); Daniel Kammer (ATA Engineering, Inc.); Jeffrey Norris (MSFC); and William Tilson (MSFC)

NESC Honor Awards

NESC Honor Awards are given each year to NASA employees, industry representatives, and other stakeholders for their efforts and achievements in engineering, leadership, teamwork, and communication. They formally recognize those who have made outstanding contributions to the NESC mission and who demonstrate the following characteristics: Engineering and Technical Excellence and Fostering an Open Environment.

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.

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.

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.

NESC Administrative Excellence Award: Honors individual accomplishments that contributed substantially to support the NESC mission.

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

NESC Director's Award

Thomas J. Horvath - In recognition of the persistence and dedication that have kept the WB-57 Remote Imaging Project viable, leading to its successful application to the AA-2 Mission

Richard J. Schwartz - In recognition of the persistence and dedication that have kept the WB-57 Remote Imaging Project viable, leading to its successful application to the AA-2 Mission

NESC Leadership Award

John D. Albright - In recognition of outstanding technical leadership in support of the Orion Pressure Control Assembly Anomaly Resolution Team

Amri I. Hernandez-Pellerano - In recognition of outstanding leadership in support of the NESC's assessment of electrical arcing risk to crew from extra vehicular activity hot mate and demate operations

Kristopher J. McDougal - In recognition of outstanding technical leadership in support of the Orion Pressure Control Assembly Anomaly Resolution Team

Robert Navarro - In recognition of outstanding project management in support of the Pilot Breathing Assessment at NASA's Armstrong Flight Research Center

NESC Engineering Excellence Award

Pavel F. Babuska - In recognition of engineering excellence in assessing the integrity of the critical bond of Avcoat material on the Orion heatshield

Eric A. Binter - In recognition of engineering excellence in the field of dynamic systems analysis improving NASA's understanding of mission critical commercial crew flight hardware

Paul A. Blelloch - In recognition of engineering excellence and innovative implementation of an hybrid parametric variation approach for addressing model uncertainty at the component level and propagating it to system-level results

James T. Burns - In recognition of engineering excellence for test design and data interpretation of environmentally assisted cracking of metals in hypergolic propellants

Anthony D. Carden - In recognition of engineering excellence for innovative system design and test execution in the acquisition of jettison data in support of the NESC's Ascent Cover Assessment

Thomas K. Evans - In recognition of engineering excellence in the support of the NESC's SpaceX Autonomous Flight Termination System and Boeing Smart Initiator Assessment providing critical insight into the flight termination system controller functional logic and the smart initiator circuit architecture

Kevin M. Hall - In recognition of engineering excellence as the analysis lead in support of the NESC's Pilot Breathing Assessment Team

Karl D. Heiman - In recognition of engineering excellence in support of the NESC's Ascent Cover Assessment Team

Reggie T. Kidd - In recognition of engineering excellence in the development and design of the Aerodynamic Buffet Flight Test vehicle

Daniel C. Kammer - In recognition of engineering excellence and innovative implementation of a hybrid parametric variation approach for addressing model uncertainty at the component level and propagating it to system-level results

William P. Leser - In recognition of engineering excellence for model development, design, and testing of materials for pressure vessel applications

Charles J. Moore, Jr. - In recognition of engineering excellence to the NESC's Ascent Cover Assessment in the field of pyrotechnic systems enabling the identification and understanding of operational risks

Jeffrey P. Norris - In recognition of engineering excellence for fabrication and testing support for the NESC's Shell Buckling Knockdown Factor Project

David Soto - In recognition of engineering excellence in support of the SpaceX Autonomous Flight Termination System (AFTS) Software Source Code Assessment, the Falcon Stage 1, and Stage 2 AFTS architecture analysis

William G. Tilson - In recognition of engineering excellence in the development and execution of custom material test methods supporting NESC's assessments in fatigue and fracture mechanics

Phillip J. Wellner - In recognition of engineering excellence and dedication as the lead aircrew life support specialist for the NESC's Pilot Breathing Assessment

NESC Administrative Excellence Award

Kylene N. Kramer - In recognition for outstanding project coordinator support for the F/A-18 and E/A-18 Fleet Physiological Episodes Assessment and the Pilot Breathing Assessment

Sandra J. Riley - In recognition of exceptional administrative support to the NESC Integration Office

NESC Group Achievement Award

Development Flight Instrumentation System Test and Analysis Assessment Team - In recognition of exceptional innovation and implementation in the development of a complete Artemis I system development flight instrumentation system analysis to assess expected flight behavior

Improved Model Correlation and Identification of Non-Linear Joints Applicable to the MPCV Team - In recognition of exceptional technical achievement in improving model correlation and identification of non-linear joints in the European Space Agency structural test article and identification of application methods for the Multi-Purpose Crew Vehicle tests

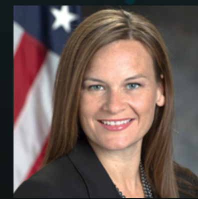
Wire and Wire Bundle Thermal Test and Analysis Team - In recognition of outstanding contributions in the development of a test apparatus, testing approach, and analytical tools to determine current carrying capacity of wires and wire bundles for aerospace vehicles

OFFICE OF THE DIRECTOR


Timmy R. Wilson
NESC
Director


Michael T. Kirsch
NESC Deputy
Director


Michael P. Blythe
NESC Deputy
Director for Safety

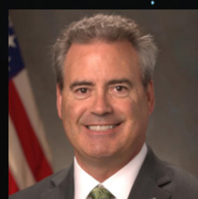

Jill L. Prince
NESC Integration
Office Manager


Dr. Daniel Winterhalter
NESC Chief
Scientist

NESC PRINCIPAL ENGINEERS


Clinton H. Cragg
LaRC


Dr. Michael G. Gilbert
LaRC


Donald S. Parker
KSC


Michael D. Squire
LaRC

NES
2019 Lea

NESC CHIEF ENGINEERS


Steven J. Gentz
MSFC


Kenneth R. Hamm Jr.
ARC


Robert S. Jankovsky
GRC


Stephen A. Minute
KSC

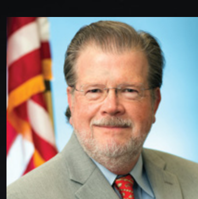

Fernando A. Pellerano
GSFC


Dr. W. Lance Richards
AFRC


Kimberly A. Simpson
JPL

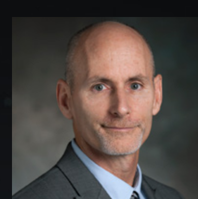
NASA TECHNICAL FELLOWS


Michael L. Aguilar
Software


Cornelius J. Dennehy
GNC

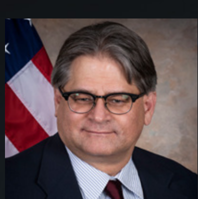

Dr. Daniel J. Dorney
Propulsion

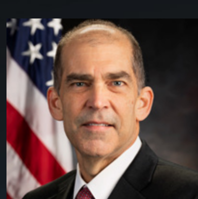

Dr. Michael J. Dube
Mechanical Systems


Dr. Robert F. Hodson
Avionics


Jon B. Holladay
Systems Engineering

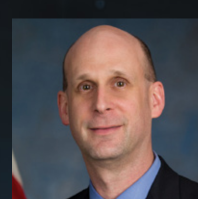

Dr. Christopher J. Iannello
Electrical Power


Dr. Joseph I. Minow
Space Environments


Daniel G. Murri
Flight Mechanics


Dr. Cynthia H. Null
Human Factors


Dr. William H. Prosser
NDE


Steven L. Rickman
Passive Thermal

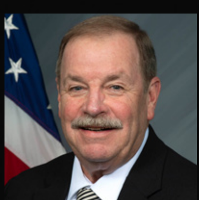

Henry A. Rotter
Environmental Control
& Life Support


Richard W. Russell
Materials

Patrick A. Martin
NASA HQ Senior SMA Integration Manager

Barry E. Wilmore
NESC Chief Astronaut

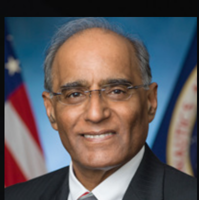
SC
adership



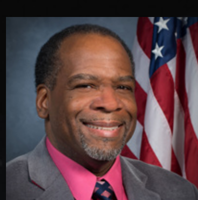
Michael D. Smiles
SSC

T. Scott West
JSC

Mary Beth Wusk
LaRC

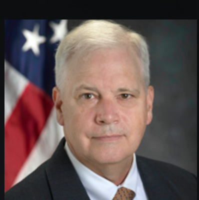


Kauser S. Imtiaz
Structures

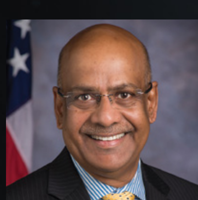


Dr. Dexter Johnson
Loads & Dynamics

Michael L. Meyer
Cryogenics



Dr. David M. Schuster
Aerosciences



Dr. Upendra N. Singh
Sensors & Instrumentation

Visit nesc.nasa.gov for bios.

Alumni

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Manager, Systems Engineering Office (2003-14)

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Timothy G. Trenkle
NESC Chief Engineer GSFC (2009-13)

Clayton P. Turner
NESC Chief Engineer LaRC (2008-09)

In Memory of
Steven S. Scott

NESC Discipline Expert for Software (2003-05) and NESC Chief Engineer at GSFC (2008-09)

Steve Scott, NESC founding member and valued colleague, passed away in August 2019. He was our first Discipline Expert (now called Technical Fellows) for Software and also served as the NESC Chief Engineer at GSFC. The NESC and the NASA community lost a great friend and distinguished engineer. He will be greatly missed.

Publications
Based on NESC Activities

Technical Papers, Conference Proceedings, and Technical Presentations

Aerosciences

1. Schuster, D.: NASA Space Vehicle Design Criteria: An Example of the Challenges in Important Document Archival and Maintenance. 2019 Knowledge Community F2F, August 20-22, 2019, Hampton, VA.

Avionics

1. Ladbury, R.; Lauenstein, J.: What's My Prior? 2019 SEE Symposium, May 21, 2019, La Jolla, CA.

Cryogenics

1. Sasson, J.; Skaff, S.; Meyer, M.; Rios, D.; Hui, T.: Densification of Liquid Oxygen – A Comparison of Numerical and Experimental Results. 28th Space Cryogenics Workshop, July 19, 2019, Southbury, CT.

Environmental Control/Life Support

1. Less, J.; Hall, K.: NASA Pilot Breathing Assessment Update and Lessons Learned. Flight Test Safety Workshop, May 6-9, 2019, Charleston, SC.

Flight Mechanics

1. Campbell, N.; Squire, M.: Entry, Descent, and Landing Time Series Data Curation Using Recurrence Networks. DATAWorks Workshop, April 9-11, 2019, Springfield, VA.

2. Pei, J.; Roithmayr, C.; Barton, R.; Matz, D.; Beaty, J.: Modal Analysis of the Orion Capsule Two Parachute System. 16th Interplanetary Probe Workshop, July 2019, Oxford, UK.

3. Pei, J.; Roithmayr, C.; Barton, R.: Modal Analysis of a Two Parachute Capsule System. AIAA Aviation Forum, June 2019, Dallas, TX.

4. Pei, J.: Nonlinear Analysis of a Two Parachute Cluster System Undergoing Pendulum Motion. AIAA Aviation Forum, June 2019, Dallas, TX.

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NASA/TM-2019-220263

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NASA/TM-2019-220265

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NASA/TM-2019-220266

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NASA/TM-2019-220270 Volume I

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NASA/TM-2019-220270 Volume II

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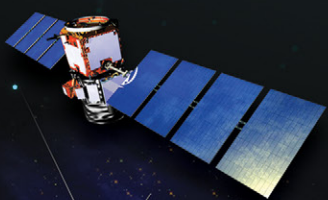
NESC Milestones

and Noteworthy Assessments




2003

NESC is Established

- CALIPSO Proteus Propulsion Bus Design
- Orbiter Flowliner Test Planning & Flight Rationale
- Cassini/Huygens Entry, Descent, and Landing
- SOFIA Acoustical Resonance

2005

NOVEMBER 2005
100th Technical Assessment

- CEV Smart Buyer Support
- Composite Crew Module Pressure Vessel
- CEV LAS Aero Evaluation


2007

JUNE 2007
200th Technical Assessment

- Shell Buckling Knockdown Factor Proposal
- Launch Abort System Risk Mitigation (MLAS)
- Kepler Reaction Wheel Usage Plan

2009

APRIL 2009
300th Technical Assessment

- COPV Life Prediction Model Development
- Crew Module Water Landing Modeling
- NASA Support to Trapped Chilean Miners

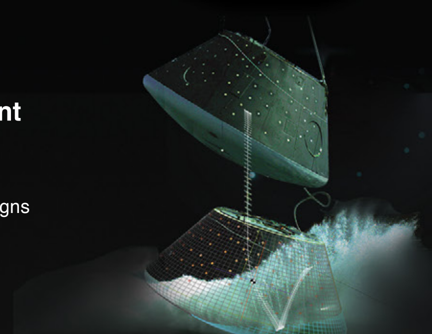
2011

FEBRUARY 2011
400th Technical Assessment

- HST Gyroscope Anomaly & Reliability Investigation
- Exploration Systems Independent Modeling & Simulation
- Alternate Spacecraft Geometries on SLS

2013

FEBRUARY 2013
500th Technical Assessment



- EMU Lithium-Ion Battery Assessment
- Assessing Risks of Frangible Joint Designs
- MPCV Avcoat Study

2014

OCTOBER 2014
600th Technical Assessment

- Testing of Subscale Ringsail & Disk-Gap-Band Parachutes
- ESD Integrated Avionics and Software V&V Plan
- Fast Coupled Loads Analysis via NTRC

2016

JULY 2016
700th Technical Assessment

- Proof Factors for COPVs
- Parts vs. Board vs. Box-level Screening Testing
- Load & Go Assessment

2018

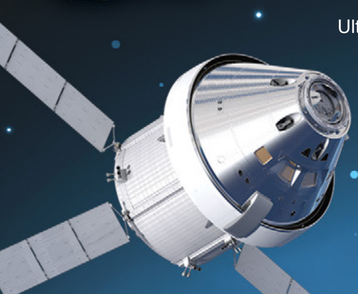
FEBRUARY 2018
800th Technical Assessment

- F/A/-18 Fleet Physiological Events
- Validation of ISS Lithium-ion Battery TR Mitigation
- Ultrasonic Level Sensors for ESM Propellant Tanks

2019

MAY 2019
900th Technical Assessment

- Orion Flight Vehicle Simulator Risk
- Pilot Breathing Assessment
- CCP Main Parachute NDE

921 Total Requests, 64 in FY19

ACRONYMS

AA	Ascent Abort
ACCP	Aerosols and Cloud-Convection Precipitation
AFRC	Armstrong Flight Research Center
AFTS	Autonomous Flight Termination System
AIAA	American Institute of Aeronautics and Astronautics
AM	Additive Manufacturing
APL	Applied Physics Laboratory
APPEL	Academy of Program/Project and Engineering Leadership
ARC	Ames Research Center
ARMD	Aeronautics Research Mission Directorate
ASTM	American Society for Testing and Materials
ATC	Air Traffic Controllers
ATD	Anthropomorphic Test Device
BD	Boundary Degrees-of-Freedom
CALIPSO	Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observations
CARA	Conjunction Assessment & Risk Analysis Program
CCP	Commercial Crew Program
CEV	Crew Exploration Vehicle
CFD	Computational Fluid Dynamics
CFM	Cryogenic Fluid Management
CLA	Coupled Loads Analysis
CM	Crew Module
CO2	Carbon Dioxide
COPV	Composite Overwrapped Pressure Vessel
CPAS	Capsule Parachute Assembly System
CPVWG	Composite Pressure Vessel Working Group
CT	Crawler Transporter
D	Diameter
DARPA	Defense Advanced Research Projects Agency
DART	Double Asteroid Redirection Test
DCR	Design Certification Reviews
DFI	Development Flight Instrumentation
EAC	Environmentally Assisted Cracking
ECLS	Environmental Control & Life Support
EDL	Entry, Descent, and Landing
EEE	Electrical, Electronic, and Electromechanical
EGS	Exploration Ground Systems
ELS	Earth Landing System
EMU	Extravehicular Mobility Unit
EPA	Environmental Protection Agency
EPR	Ethylene Propylene Rubber
ESD	Exploration Systems Development
ESM	European Service Module
ESMATS	European Space Mechanisms and Tribology Symposium
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FEA	Finite Element Analysis
FEM	Finite Element Model
FPMU	Floating Potential Measurement Unit
FTS	Flight Termination System
FY	Fiscal Year
GG	Gas Generator
GNC	Guidance, Navigation, & Control
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
HCB	Hurty/Craig-Bampton
HDBK	Handbook
HEO	Human Exploration and Operations
HPV	Hybrid Parametric Variation
HSI	Human Systems Integration
HST	Hubble Space Telescope
ICON	Ionospheric Connection Explorer
ICPS	Interim Cryogenic Propulsion Stage
IEEE	Institute of Electrical and Electronics Engineers
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JWST	James Webb Space Telescope
KSC	Kennedy Space Center
LAM	Launch Availability Model
LaRC	Langley Research Center
LAS	Launch Abort System
LEM	Lunar Excursion Module
Li-Ion	Lithium-Ion
LLIS	Lessons Learned Information System
LOX	Liquid Oxygen
LSP	Launch Services Program
LSTC	Livermore Software Technology Corporation
LV	Launch Vehicle
LVSA	Launch Vehicle Stage Adapter
M&P	Materials and Processes
M&S	Modeling and Simulation
MacOS	Macintosh Operating System
MAF	Michoud Assembly Facility
MBSE	Model-Based Systems Engineering
ML	Mobile Launcher
MLAS	Max Launch Abort System
MLP	Mobile Launch Platform
MMOD	Micrometeoroid and Orbital Debris
MOWG	Mission Operations Working Group
MPCV	Multi-Purpose Crew Vehicle
MSA	MPCV Stage Adapter
MSFC	Marshall Space Flight Center
MTSO	Management and Technical Support Office
NASA	National Aeronautics and Space Administration
NASCAP	NASA and Air Force Spacecraft Charging Analysis Program
NCE	NESC Chief Engineer
NDE	Nondestructive Evaluation
NDSB2	NASA Docking System Block 2
NESC	NASA Engineering and Safety Center
NIO	NESC Integration Office
NOVICE	Software Suite for Space Systems Radiation Effects
NPV	Nonparametric Variation
NRB	NESC Review Board
NTP	Nuclear Thermal Protection
NTRC	Norton-Thevenin Receptance Coupling
OCE	Office of the Chief Engineer
ORDEM	Orbital Debris Engineering Model
PAMELA	Payload for Antimatter Matter Exploration and Light-Nuclei Astrophysics
PBA	Pilot Breathing Assessment
PE	Physiological Episodes
PE	Principal Engineer
PIM	Plasma Interaction Model
PLM	Product Lifecycle Management
POD	Probability of Detection
PSP	Parker Solar Probe
PTV	Parachute Test Vehicle
PVC	Performance, Verification, and Characterization
QSMA	Quasi-Static Modal Analysis
RefProp	Reference Fluid Thermodynamic and Transport Properties
RPCM	Remote Power Control Module
RRM3	Robotic Refueling Mission 3
S&I	Sensors & Instrumentation
SBKF	Shell Buckling Knockdown Factor
SCAF	Spacecraft Anomalies and Failures
SE	Systems Engineering
SE&I	Systems Engineering and Integration
SEE	Single Event Effects
SET	Systems Engineering Team
SID	System Identification
SLS	Space Launch System
SM	Service Module
SMD	Science Mission Directorate
SME	Subject Matter Expert
SOFI	Spray-on Foam Insulation
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOTA	State-of-the-Art
SOW	Statement of Work
SRB	Solid Rocket Booster
SSC	Stennis Space Center
STMD	Space Technology Mission Directorate
STS	Space Transportation System
TDT	Technical Discipline Team
TM	Technical Memorandum
TPS	Thermal Protection Systems
TR	Thermal Runaway
TRA	Technical Readiness Assessment
TRADES	TRAnsformative DESign
UF	University of Florida
UQ	Uncertainty Quantification
USAF	United States Air Force
USN	United States Navy
VAB	Vehicle Assembly Building
V&V	Verification and Validation
WFF	Wallops Flight Facility
WSTF	White Sands Test Facility
XRISM	X-ray Imaging and Spectroscopy Mission

National Aeronautics and
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NP-2019-10-076-LaRC