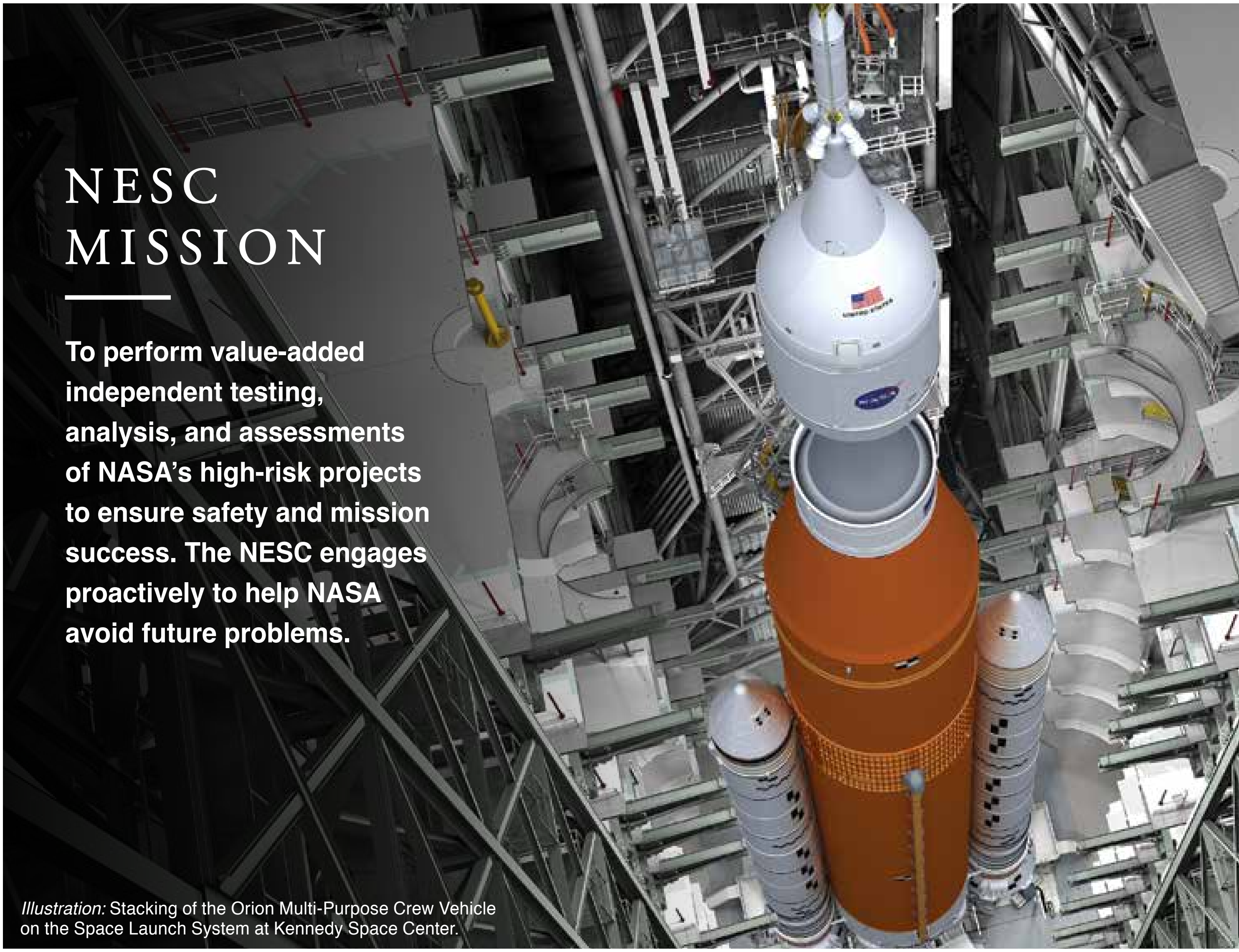
National Aeronautics and
Space Administration

2017 TECHNICAL update

NASA Engineering & Safety Center

www.nasa.gov

Safety Starts with En



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.

Illustration: Stacking of the Orion Multi-Purpose Crew Vehicle on the Space Launch System at Kennedy Space Center.

Members of the NESC Team, 2017.

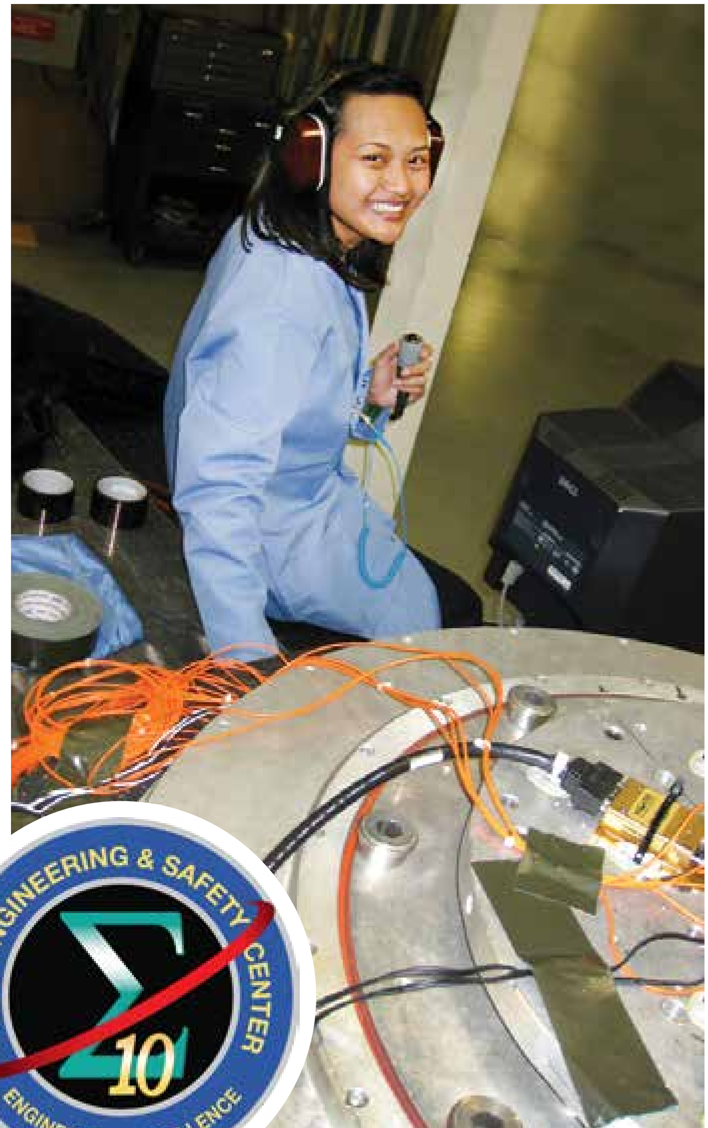
For general information and requests for technical assistance visit us at:

nesc.nasa.gov

For anonymous requests write to:

NESC
NASA LANGLEY RESEARCH CENTER
MAIL STOP 118
HAMPTON, VA 23681-2199

gineering Excellence



Sarah Pham conducting vibration testing of flight-test avionics.

The NESC's unique insignia has its roots in the early Mercury program.

"...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. While Wally Schirra's spacecraft represented the 7 Mercury astronauts, the 10 in the NESC insignia represents the 10 NASA Centers. The NESC draws upon resources of the entire Agency to ensure engineering excellence.

Contents

8-foot-diameter honeycomb-core sandwich composite cylinder positioned in MSFC autoclave.

Completed cylinder will be tested to failure in the Shell Buckling Knockdown Factor Project.
see pages 42-43

From
NASA Leadership

Robert M. Lightfoot, Jr.
NASA Acting Administrator

"Today, the nation's eyes are focused on NASA to deliver a determined and sustainable course for the future of space exploration. In developing our capabilities to reach beyond our Earth-Moon system, the Agency will continue to ready its planned Exploration Missions, EM-1 and EM-2. The first is an uncrewed flight of NASA's newest spacecraft, the Orion Multi-Purpose Crew Vehicle, while EM-2 will carry its first crew aboard. Both missions will build on the hard work already well underway on Orion, its launch vehicle, the Space Launch System, and the Ground Systems Development and Operations enabling launch. Similarly, the Commercial Crew Program will mark the return of launching crews to the International Space Station from the United States as our two providers continue making progress toward this key Agency milestone and capability. The NESC's role in these efforts is more important than ever. These programs and others across the Agency in science, aeronautics, and technology development will continue to rely on the NESC's strong technical expertise, leadership, and engineering solutions they provide when challenges arise. Public interest in and expectations of NASA have increased, as demonstrated by the reestablishment of the National Space Council - further emphasizing the critical role NESC's assessments play in reducing risk and enabling the advancement of NASA's mission and our nation's goals for the future exploration of space."

Ralph R. Roe, Jr.
NASA Chief Engineer

"In 2017, as the Agency is in the middle of the most development it has seen since Apollo, the NESC has stepped up to provide technical support to our programs in addition to their independent role. Whether it's testing the use of frangible joints, EEE parts, or composite overwrapped pressure vessels, the NESC is able to assemble the best experts in the nation to address critical issues. Being able to balance technical support with its role of independence allows the Agency to leverage NESC's technical experts to the maximum extent possible. Each NESC assessment has furthered NASA goals and contributed directly to the Agency mission through better-informed decision-making and an overall reduction of risk. It's a strength that NASA will continue to rely on as the Agency moves the nation forward in the upcoming years in aeronautics, science, technology, and space exploration."

Ensuring Engineering Excellence Today and into the Future

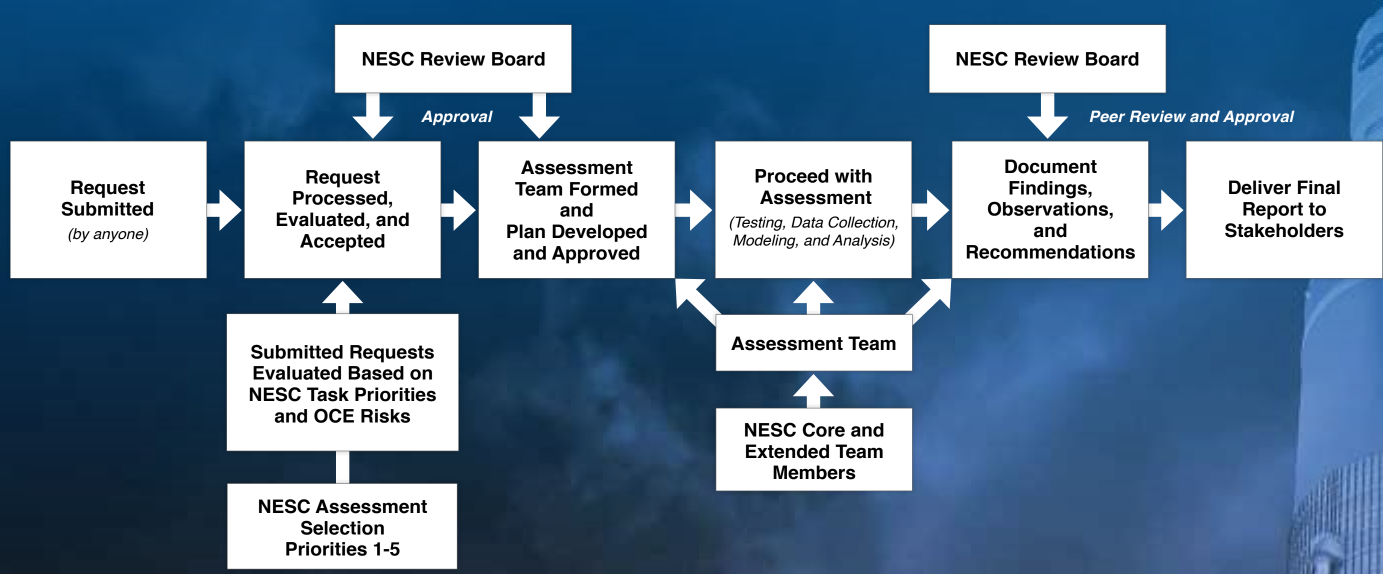
Behind every remarkable achievement, every iconic spacecraft, every new technology, every explored world, are people. This NESC Technical Update presents some accomplishments of those people, from engineers who have been with NASA since Apollo to new faces fresh out of college. They have all worked with the NESC this past year to find solutions to the Agency's toughest technical problems.

The NESC is structured to quickly build assessment teams to address technical issues that can arise anywhere within or external to NASA. These teams comprise engineers and scientists drawn from 21 different technical disciplines, referred to as Technical Discipline Teams (TDT). Each TDT is typically led by a NASA Technical Fellow, who is the Agency lead for that discipline. While the Technical Fellows work directly for the NESC, they are still an Agency-wide resource. The members of their TDTs represent the highest level of discipline expertise available – drawn from all 10 NASA Centers, other government agencies, academia, and industry. In addition to supporting the NESC, the NASA Technical Fellows are also a fundamental part of the Office of the Chief Engineer-supported capability leadership initiative that is fundamentally changing the way the Agency manages engineering resources, and promises to improve efficiency, reduce long-term operating costs, and improve the health of NASA's technical disciplines.

The Technical Fellows are part of the NESC core team, which also includes the Principal Engineers, NESC Integration Office, NESC Chief Engineers, and the Management and Technical Support Office. All of the elements of the core team come together in the NESC Review Board (NRB), which provides diversity to its review and approval process, because people with different experience bases and technical backgrounds approach each issue from a different vantage point. The results are a broader understanding of each technical problem and its solutions.

While the areas of emphasis for the NESC have evolved over the 14 years of its existence, its commitment to "safety starts with engineering excellence" has not waivered. The NESC was formed in the wake of the Columbia accident and, for the first several years, spent a large fraction of its resources on the operational crewed programs of the Space Shuttle and the International Space Station (ISS), while also supporting many of the science and aeronautics activities. Today, while the ISS, science, and aeronautics are still important customers for the NESC, the Space Shuttle has been retired, and a heightened focus on new crewed spacecraft systems – the Orion Multi-Purpose Crew Vehicle, Space Launch System, Ground Systems Development and Operations, and Commercial Crew Program – is one of the NESC's priorities. With such large programs and three completely different

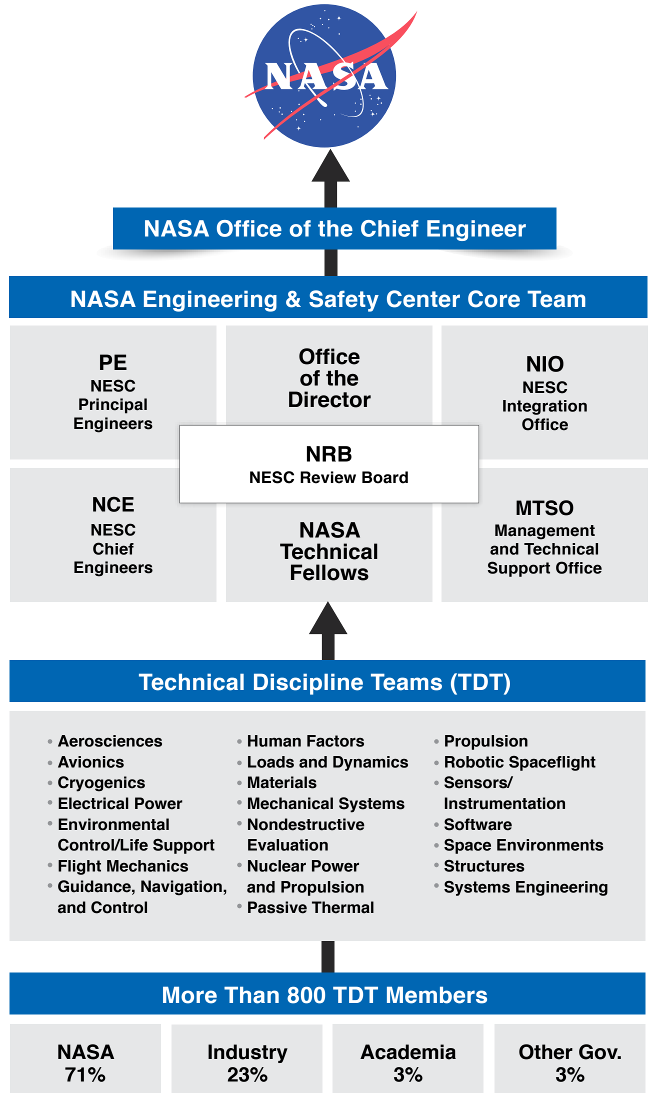
PERFORMING NESC ASSESSMENTS



vehicles in development, there are many challenges facing NASA and the commercial crew providers. The NESC is helping to identify and address "gaps" in the designs and what is required or what is in the best interest of safety and mission success.

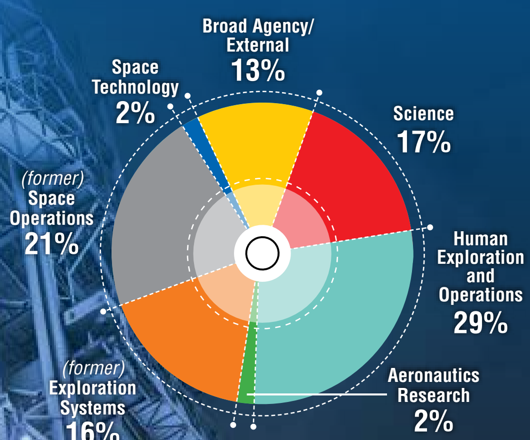
The NESC is also dedicated to ensuring continuity of "safety starts with engineering excellence." As people retire or otherwise move on, a new generation of engineers is needed to step up and fill the voids that are left. This is a challenge, but it is also an opportunity to acquire fresh ideas and perspectives. The NESC places new engineers on many of their assessment teams to learn from the more experienced team members. In fact, all of the team members learn from each other – new and experienced. In this way, knowledge is continually transferred, and this helps to ease and shift the expertise load when someone leaves.

It is this diversity in experience and technical backgrounds that the NESC promotes, values, and relies on to solve the Agency's toughest technical issues, and it is this same diversity that strengthens the NESC and NASA as an agency.

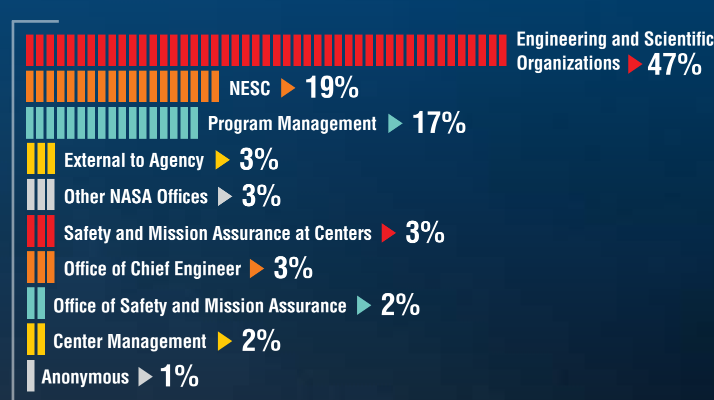


ACCEPTED REQUESTS SINCE 2003:

767 total, 53 for FY17

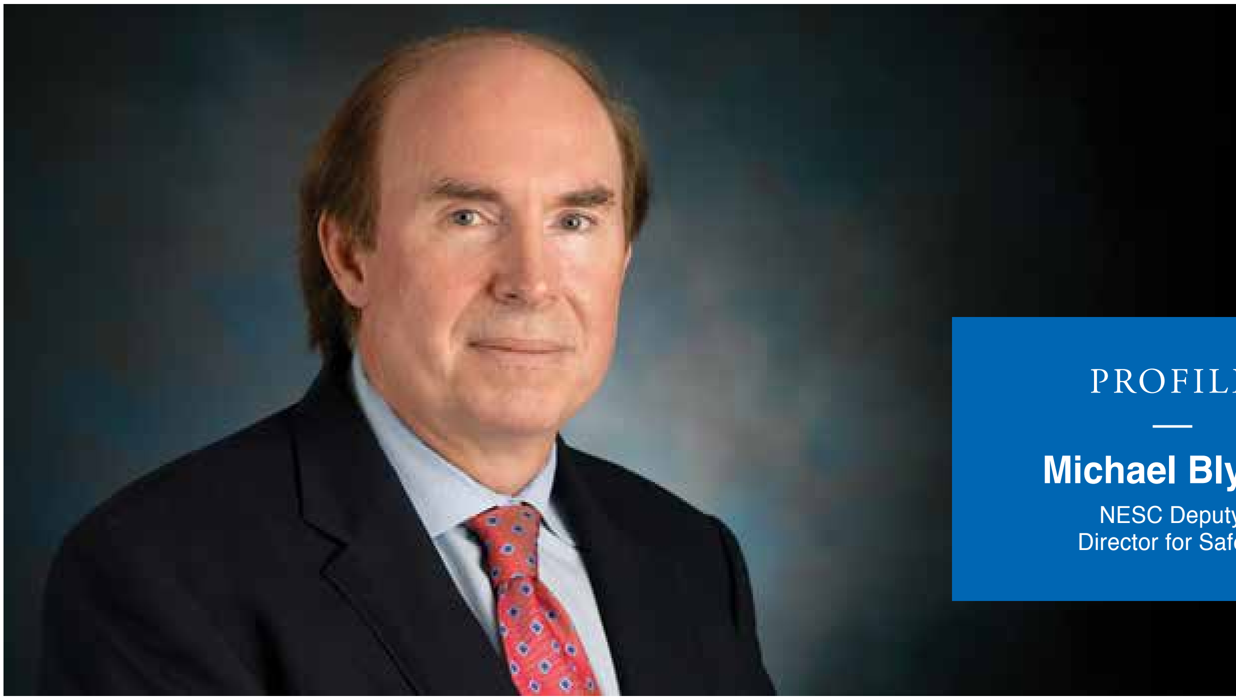


Accepted Requests by Mission Directorate



Sources of Accepted Requests

Data as of September 30, 2017



PROFILE

Michael Blythe

NESC Deputy
Director for Safety

Safety First: How the NESC Maintains a Deeply Rooted Culture of Safety

In 2009, Mr. Michael Blythe joined the NESC Director's Office as the Deputy Director for Safety (DDS). His role is an important one – maintaining a robust safety culture. It's a job that calls on his decades-long career as a NASA engineer and his ability to communicate with people across all disciplines and NASA Centers.

Fostering a safety culture starts with communication, and he casts a wide net to ensure that culture stays entrenched within the NESC and across the Agency. As the NESC's interface to the NASA safety community, job one is "involving the community in our NESC activities where it makes sense to do so." That includes offering the NESC's services to help solve technical issues and ensuring the safety community is well represented on assessment teams.

The job as DDS is meeting intensive, but his participation is crucial in order to stay in touch with the safety community at large. "I do attend a lot of meetings," he said. "I'm that guy in the background helping people, making sure things don't get overlooked." He meets regularly with NASA's Office of Safety and Mission Assurance (OSMA) and the NASA Safety Center. He also serves as the NESC representative for Safety and Mission Success Reviews (SMSR), the Safety Culture Working Group, Mishap Investigation Board Working Group, the System Safety Steering Group, and Standing Review Boards (SRB).

Mr. Blythe has chaired several SRBs, which provide independent reviews of projects or programs at specific life-cycle milestones. They are long term commitments, lasting for the duration of the project – from initial design to post launch. For NASA's Stratospheric Aerosol and Gas Experiment (SAGE III) Project, he assembled the SRB team and organized each milestone review. "A few weeks before each review, we received the project's updates and spent time going through their material to make sure we understood everything, noting areas where we might have concerns or need clarification. At the review we focused on areas where we could help the project and show them where they were on the mark and where there may be gaps they need to address."

Offering an Independent Perspective

It's the approach he takes with every SRB he chairs – to offer expertise and provide actions the project can take to help them be successful. "You can't always see the forest for the trees when knee-deep in a project. That's when it's good to have an outside, independent team help you find things you may have overlooked. We point out issues that if not addressed early could become bigger problems."

The SAGE III SRB reviews occurred periodically over about 4 years. The mission launched to its post on the International Space Station in early 2017 and is now producing science data.


International Space Station (ISS)


Illustration of Space Launch System on mobile launcher


SAGE III instrument on the ISS

"WE'VE MADE A LOT OF IMPORTANT CONTRIBUTIONS... **THE AGENCY RECOGNIZES THE VALUE OF THE NESC** AND I'M HONORED AND BLESSED TO BE A SMALL PART OF A WELL-MANAGED, SUCCESSFUL ORGANIZATION."

He is now chairing the SRB for NASA's GEDI Project, Global Ecosystem Dynamics Investigation Lidar, which will provide high resolution laser ranging of the Earth's forests and topography.

Providing Constructive Advice

While his focus is safety management, he still supports NESC assessments. "I still wear an engineering hat and participate in assessments where I think I can have an impact." He recently served as the deputy lead for an assessment to determine the risks associated with loading cryogenic propellants after a crew is onboard a flight vehicle, a departure from the normal approach of loading propellants prior to crew ingress. "I served as the backup to the assessment lead, and used my engineering background to serve as the avionics lead."

NESC assessments offer him the opportunity to share what he's learned. "I always try to provide constructive advice, advice that people can do something with. I feel that if you can't offer constructive options, then you haven't really helped anybody. Recently, we reviewed the Exploration Systems Development integrated hazard development process. It was a tough assessment, but we provided them constructive feedback on their integrated hazards process for the Orion Multi-Purpose Crew Vehicle, Space Launch System, and Ground Systems Development and Operations Programs. I've always gone in with a 'how can I help you' approach and that has worked. We've received positive feedback in helping projects or programs find holes they didn't know they had."

After many years at NASA, Mr. Blythe has watched the safety culture at the Agency evolve over the years, witnessing this first hand at the SMSRs, which are held before every NASA launch in preparation for flight readiness reviews.

"I attend every SMSR for every Agency mission. At each SMSR, the NASA Chief Engineer and the OSMA Chief ask if anyone has any concerns or any dissenting opinions. They offer everyone a chance to speak up. They listen because they want all the information they can get to make informed decisions. I've seen those dissenting opinions go up the line from the engineer to senior management and all the way to NASA Headquarters. The process worked. The dissents were heard. That's a change that's made an impact."

Working on NESC assessments lets him contribute to the Agency's success in many ways and that's an aspect of the job he really enjoys. "It's the best place in the Agency to work. There are a lot of sharp people here and it's a joy to work with them. We've made a lot of important contributions to the Agency. The NESC, I think, is more respected now than it was even 5 years ago. People finally know who we are. The Agency recognizes the value of the NESC and I'm honored and blessed to be a small part of a well-managed, successful organization."

PROFILE

Stephen Minute

NESC Chief Engineer at Kennedy Space Center

NCEs: The NESC's Crucial Link to NASA Centers

Sometimes to gain a new perspective on how to solve a problem, Mr. Stephen Minute has found he has to look through a wider lens.

Right after graduation from Penn State in 1983, Mr. Minute joined NASA to work as a fluid systems engineer with the shuttle main propulsion system at Kennedy Space Center (KSC). Over the next 20 years, he became a self-described KSC man, with a deep-rooted sense of place and perspective that evolved over 20 years of working on the Space Shuttle Program and playing a part in countless NASA launches.

But in 2006, when selected to serve as the NESC Chief Engineer (NCE) at KSC, he quickly realized that to be a valuable NCE, he was going to have to expand his KSC perspective to a NASA-wide point of view. When the NESC organization began in 2003, its founding principles included providing independent test and analysis to offer a second, broader-focused perspective to some of NASA's most challenging issues. NCEs play a big role in ensuring those perspectives and ideas maintain a steady flow between the NASA Centers and the NESC.

Widening the Lens

For Mr. Minute, changing his thinking and his sometimes Center-biased approach to solving problems was a challenge for him, but as he participated in more and more NESC assessments, he watched that bias start to disappear. He remembers his first major NESC assessment that helped him start to broaden his approach, the Max Launch Abort System (MLAS). The NESC was tasked with designing, building, and testing an alternate launch abort system for the former Crew Exploration Vehicle. The assessment team had people from all across NASA, as well as industry and mentors from the Apollo, International Space Station, and Space Shuttle Programs.

"That was the first real significant assessment I was on, and I really got to see a very diverse cross section of the Agency all coming together to work on this one project." His job was processing flight hardware, a job he had done before at KSC. The assessment gave him the opportunity to work with personnel from NASA's Wallops Flight Facility.

"I came in thinking I knew everything about processing flight hardware, but then I saw how Wallops did it," said Mr. Minute. "They didn't have the same constraints I had from working on human spaceflight hardware. They had different capabilities and ways of doing business, and they could come at the issue from a different perspective that highlighted solutions I hadn't even thought about. The assessment made me realize there were a lot of smart people across NASA and they all have good ideas worth listening to. Having those conversations back and forth broadened my perspective."

Building a Bridge to the NESC

At every KSC meeting and interaction, Mr. Minute now looks at problems and concerns through the NESC independent lens. "Because of the NESC's interaction with a lot of other Centers and programs through its assessments, I can bring a different perspective from that of my own Center. Sometimes being at one Center or in one organization can limit experiences," he said. "NCEs can sometimes bring a different perspective to the thought process."

For the past few years, he has been bringing that different perspective to NASA's Commercial Crew Program (CCP). Residing at KSC, CCP is working with its commercial partners like SpaceX and Boeing to develop the spacecraft that will eventually launch NASA's astronauts back into space from U.S. soil. Maintaining insight into these programs is one of the NASA Chief Engineer's top Agency risks, one of the NESC's prime areas of focus for its assessments, and what takes up the majority of Mr. Minute's time as an NCE. "I work with the CCP, its partners, and engineering to try and bring NESC expertise to help them in any way we can. That's my number one priority."

"I WORK WITH THE CCP, ITS PARTNERS, AND ENGINEERING TO TRY AND **BRING NESC EXPERTISE TO HELP THEM** IN ANY WAY WE CAN. THAT'S MY NUMBER ONE PRIORITY."

"I communicate with people at all levels and disciplines regarding project concerns, trends, and patterns that we're seeing. I sit in on a large number of technical meetings, and I spend a lot of time talking with engineers in the hallways, calling them, and asking them questions," he said. "I also participate in technical reviews and boards at KSC – to act as another set of eyes on engineering panels." When he sees an opportunity for the NESC to help out with work going on at KSC or receives requests from KSC projects and programs for NESC assistance, he brings those concerns and issues to the NESC Review Board (NRB). The NRB provides a board-level technical review of all NESC activities and assessments and the weekly NRBs give Mr. Minute the opportunity to share, as well as gain, insight from other NCEs and NASA Technical Fellows. He also meets weekly with his fellow NCEs from NASA's other nine Centers. "We'll talk about what's going on and what we are learning at our own Centers. It's a back and forth communication," which he continues by sharing with KSC any lessons learned that are pertinent.

Mr. Minute also keeps tabs on KSC expertise to help staff the NESC's assessment teams, the majority of which come from NASA's engineering organizations. "NCEs know what their Center's expertise or lab capabilities are and pull those people and facilities in if needed. We make sure those resources are available."

"It's not easy being a conduit," he said. "But this is the best job I've had. I just learn so much. Because the NESC is fact-oriented and tries to provide unbiased technical input, it's really helped me to be unbiased and look at all sides of the story. Sometimes I used to let my biases do my thinking for me, but now I try to understand the other side, all of the different perspectives. You just have to try to understand them and use them to get to a common solution. There are so many smart people at the Agency who have just as good or better ideas, and they can help if we let them."

THE ROLE OF AN NCE

- Serve as liaison between resident Center and NESC
- Foster proactive involvement with programs and projects at resident Center
- Provide technical expertise and technical resources external to the program/project to assist with resolving issues
- Provide program/project insight to NESC through participation at major boards and panels
- Review assessment requests, clarify issues, perform risk assessments, recommend NESC courses of action, develop associated cost estimates, and present this information to NRB
- Manage NESC resources at resident Center
- Assist Principal Engineers and NASA Technical Fellows with staffing NESC technical activities with resident Center resources
- Contribute to Technical Discipline Teams and NESC technical activities – both assessments and support activities – based on their areas of expertise

Photo: Mr. Minute led development of ground processing plans and procedures for the MLAS flight hardware – pictured here inspecting a parachute static line used on the flight test.

Mentoring the Next Generation of Engineers

After Dr. William Walker started his graduate degree in 2012, he applied for a fellowship program at Johnson Space Center (JSC). He was looking for opportunities to gain experience in understanding lithium-ion (Li-Ion) battery thermal runaway (TR), the topic on which he would eventually write his dissertation.

"They plugged me into the work that the NESC was doing on TR. Everything fit in perfectly," said Dr. Walker. He is now an engineer at JSC assisting Mr. Steven Rickman, NASA Technical Fellow for Passive Thermal, on an NESC assessment to develop calorimetry technology to better understand how a battery's thermal energy is dispersed during TR *(see center box)*.

Mentoring is a fundamental part of Mr. Rickman's philosophy. "I'm probably the biggest advocate of mentoring you will find. I've always felt it was important," said Mr. Rickman. "Early career engineers and engineering students need to do their time in the trenches. They need to get a number of years of hands-on applied engineering work and get exposure to a wide variety of problems. From that they gain wisdom they can apply to problems in the future."

The assessment has been a great learning experience for Dr. Walker. "I'm not only doing data interpretation, but I've also been involved in the design of hardware, providing thermal expertise as I can, and I've been a part of the tests as they happen."

Dr. Eric Darcy, the assessment's technical lead, is a registered mentor who has worked with many students. "I'm very hands-on in terms of tagging up routinely and making sure they don't have roadblocks keeping them from doing their work. I find it's important for them to not only design, but also build and test – to experience the whole process while they are here," he said.

Li-Ion BATTERIES

Li-Ion batteries have garnered attention because of thermal runaway (TR) issues. TR can occur due to internal cell failures, resulting in elevated temperatures and the release of hot gases and flames. The NESC has performed assessments to develop TR severity reduction measures and improve the design of its Li-Ion batteries used in spaceflight. Data obtained from the calorimeter will aid in the development of thermal mathematical models to improve TR mitigation and inform future battery designs.

An internship led Ms. Natalie Anderson to JSC and the calorimetry assessment. "I set up the calorimeter for testing, deciding what would be different from test to test, gathering data, and reducing it down for the person doing the thermal analysis," she said. "I really enjoyed the hands-on aspect. It's fun when you can put the pieces together and start testing to see if it really works."

Now a new graduate student, Ms. Anderson said Dr. Darcy was a great mentor. "He answered questions, and if I wasn't sure about something, he was accessible. He didn't treat me like an intern who didn't know anything. He would ask me what I thought and let me prove myself."

Mr. Jacob Darst is a former co-op student now working at NASA. "I've been designing and refining components for the calorimeter system," he said. "I can say I have my thumb print on every piece of this device. I've been part of the design, manufacturing, and testing. I've spent countless hours wiring it up, firing it, and tending to it. With this calorimeter, we can create better mitigation systems and better battery pack designs. I may be just daring to dream, but this could be a device that's eventually used at NASA and in industry."

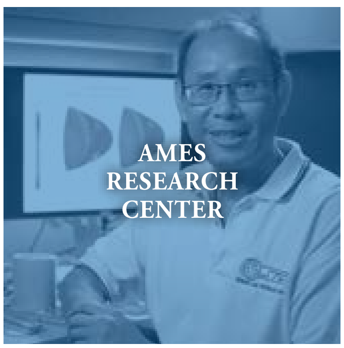
Mr. Rickman likes that enthusiasm. "Here they get to apply what they've learned in school to real-world problems. Whether you are a co-op, an intern, or an early career engineer, you'll see that the information you might need to solve a problem isn't in a textbook. You have to be creative and invent things on the fly," Mr. Rickman said.

"Many engineers would attest that not everything we know is written down, despite our best efforts to do so," he added. "A lot of what we know is in our heads. A good way to transfer knowledge is for young engineers and seasoned engineers to work side by side to make sure that flow of information takes place."

"A GOOD WAY TO TRANSFER KNOWLEDGE IS FOR **YOUNG ENGINEERS AND SEASONED ENGINEERS** TO WORK SIDE BY SIDE TO MAKE SURE THAT FLOW OF INFORMATION TAKES PLACE."

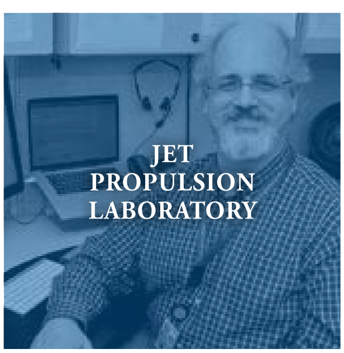
Assessment Team *(left to right):*
Dr. Eric Darcy; Jacob Darst; Dr. William Walker; Steven Rickman; Natalie Anderson (not shown)

For more on Li-Ion batteries, see pages 39 and 51.



NESC at the Centers

Drawing upon Resources of the Entire Agency to Ensure Mission Success



NASA Ames Research Center (ARC) continues its support of NESC activities by leveraging its unique and diverse capabilities including: aeronautics research; computational fluid dynamics; wind tunnel testing; entry, descent, and landing (EDL) modeling; arc jet testing of advanced thermal protection materials; and human factors research. Many of these areas of expertise have been engaged to assist with NESC technical assessments and in support of the Technical Discipline Teams (TDT) throughout 2017. ARC has representatives on 17 NESC TDTs. ARC continues to support independent EDL modeling for the Commercial Crew Program (CCP) using expertise in aerothermal analysis and high speed computation to provide validation of entry system environments and designs for NASA's commercial partners. Experts in data mining and information technology have assisted with NESC efforts to understand physiological events associated with F/A-18 aircraft for the Navy. ARC engineers continue to support major discipline reviews for CCP, Orion Multi-Purpose Crew Vehicle, and the Space Launch System in the areas of structures and materials. Both the Technical Fellow for Human Factors and acting Technical Fellow for Structures are currently located at ARC.

Modeling Entry, Descent, and Landing of Commercial Crew Vehicles

As NASA's commercial crew providers develop and finalize their designs for the Boeing Starliner and SpaceX Crew Dragon, three senior research scientists have developed analytical models of these vehicles and are running multiple simulations to provide independent verification and validation of the commercial partner designs. Their work supports the NESC's assessment to provide independent modeling and EDL simulation for CCP.

"Our group's area of expertise is aerothermodynamics and material response modeling," said Dr. Steven Sepka, who models the thermal protection systems that shield vehicles from the extreme heat of reentry and writes code to calculate margins. "The EDL group with the NESC is a very senior group that helps provide oversight as the CCP helps the commercial providers develop their spacecraft. We help where we can, performing checks and making sure everything looks good."

"If we're given a potential trajectory for a spacecraft's EDL, aerothermodynamics will determine the heating environment the craft will encounter," he said. "Once we understand that environment, we can also determine and model how the spacecraft's material will respond." The team has performed hundreds of these independent checks in support of CCP verification reviews.

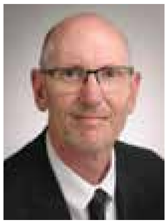
"For each reentry there's a need for aerothermal analysis," said Dr. Yehia Rizk. "Each application is somewhat different from the other. Using tools like computational fluid dynamics, we try to predict the environment for all possible trajectories and identify any that might exceed the spacecraft's material limits, which could cause a failure. Our independent analysis assists in determining the accuracy of the aerothermal environment developed by our commercial providers," he said. "It's challenging, using computational tools to predict what will happen in real life."

Senior Scientist Mr. Loc Huynh gathers all of that information into an aerothermal database. "The database covers the entire flight envelope for every trajectory. At every step we want to know the aerothermal characteristics of the vehicle, how much heat is generated, what kind of shielding is used, and the kinds of pressure the vehicle encounters," he said. "The providers have their own databases, but our database allows us to maintain an independent check."

This assessment marks the first time Dr. Sepka has worked with the NESC. "As we uncover different issues or identify a need, we can make a call," he said of the ability to tap into the NESC's resources of technical expertise. "I'm happy to be involved with such a great group of people. They are the highest caliber in terms of technical knowledge."

"Unlike other projects we work on, the NESC goes across not only Ames, but Langley and Johnson," said Dr. Rizk. "We interact with people from different groups who contribute to the effort and we're exposed to different opinions. This is a multi-Center team," he said. Every time you can interact with more people, the more beneficial it is."

Mr. Huynh finds the work he is doing for the NESC challenging as well as enjoyable. "We have a lot of freedom to do what we need to do," he said. "And when I think about working on something that flies in space, it just makes me feel good."

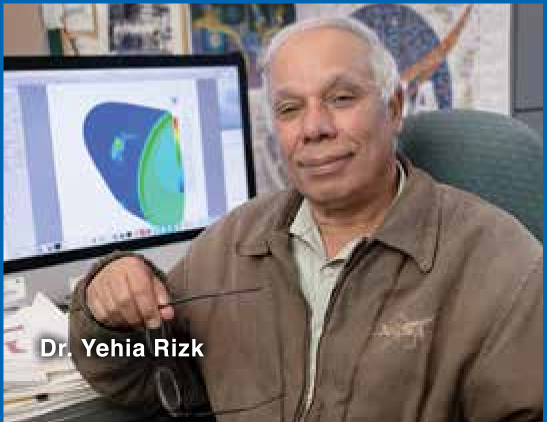


Kenneth R. Hamm, Jr.
NESC Chief Engineer

25 ARC *employees supported NESC work in FY17*

AMES RESEARCH CENTER


Dr. Steven Sepka


Dr. Yehia Rizk


Loc Huynh

The Armstrong Flight Research Center (AFRC) provided engineering technical expertise and support to the NESC for numerous activities including the SpaceX Falcon 9 Composite Overwrapped Pressure Vessel (COPV) Instrumentation Team, the composite Shell Buckling Knockdown Factor (SBKF) Project, the Composite Pressure Vessel Working Group, and the Frangible Joint Empirical Test Program. In particular, the AFRC Fiber Optic Sensing System (FOSS) Team instrumented, supported testing, and analyzed fiber optic temperature and strain measurements of multiple composite test articles. The team developed new and innovative attachment techniques to measure the physical response of COPVs in liquid nitrogen. These activities served as a step toward the eventual goal of testing COPVs in densified liquid oxygen for launch vehicle applications. Engineers, instrumentation specialists, and technicians traveled to various locations throughout the year to support sensor characterization, installation, and large-scale testing in support of these programs.

NESC Benefits from FOSS Technology

Tests and analyses performed during three NESC assessments in 2017 required the use of AFRC's FOSS Laboratory, a specialized facility that uses fiber optics (FO) to measure strain, temperature, shape deformation, loads, and other key parameters to understand a structure's performance. Fiber optics were used to get a distributed strain measurement for the NESC's SBKF assessment where, during testing, an 8-foot tall/8-foot diameter cylinder was crushed much like a soda can by a 900,000-pound load. To understand what happened as the structure was compressed to failure, the cylinder was extensively instrumented with 16 fibers, each the width of a human hair and 40 feet long, which allowed data retrieval from measurements on both the inner and outer mold lines.

"The FO system allows us to record a strain measurement along every half inch of each 40-foot long fiber. For this application, we sampled all strain sensors 10 times per second. That's approximately a thousand measurements per fiber across 16 fibers simultaneously – and almost 160,000 measurements per second," said Mr. Francisco Peña of the FOSS Structures Laboratory. In this case, FO painted a clear picture, for example, of stress concentrations that conventional strain gage and thermocouple technology may have missed.

"We work hand-in-hand with NASA organizations, and as we transition to new FO techniques, we keep them abreast of how they can apply this technology," said Mr. Allen Parker, who works in the FOSS Systems Laboratory developing the systems used to pull information from the FO sensors.

Fiber optic sensors were also used on COPVs in support of NESC assessments. "We instrumented a 100-gallon COPV with fiber optics much like the SBKF cylinder, but on a smaller scale," said Mr. Parker. As the COPV was pressurized, the FOSS Team analyzed strain and temperature data to understand the structure's response.

"We are tasked with using FO sensors to look at a multitude of real-world problems within the Agency and beyond," added Mr. Peña. "We're glad FOSS technology could help the NESC better understand structural responses and come up with solutions."

Evolution of Technology

Mr. Anthony Piazza has worked in instrumentation at NASA for more than 25 years and has worked with the FOSS Laboratory overseeing the attachment of fiber optics for the NESC SBKF and COPV assessments. His main area of focus is making accurate structural strain and temperature measurements over a very broad temperature range, from cryogenic temperatures to 1800° F.

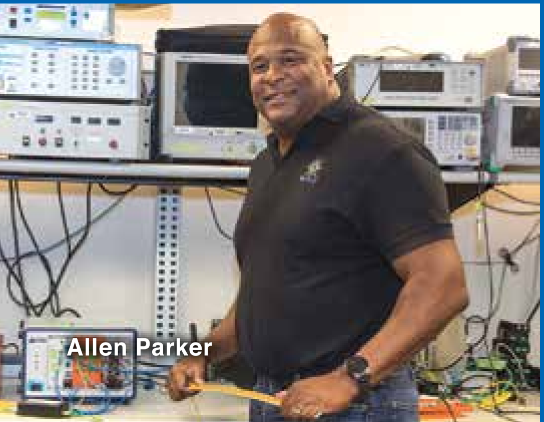
"I develop attachment techniques to ensure electrical strain gages and fiber optic sensors provide accurate measurements when bonded to structures that are exposed to extreme temperature environments. This involves characterizing these sensors for measurement errors caused by high temperatures seen during reentry or the extremely low temps we get with cryogens," said Mr. Piazza.

Over his 25 years, he has watched technology change from a completely electrical-based instrumentation. "We have transitioned to optical methods in most applications for making strain and temperature measurements. We still use strain gages and thermocouples, but more and more we are seeing the coverage of fiber dwarf that of regular strain gages. We get so many more measurements along a single fiber," he said. "We're not replacing electrical methods, but at AFRC we are using FOSS in most everything we're doing."

Dr. W. Lance Richards
NESC Chief Engineer

24 AFRC *employees supported NESC work in FY17*

ARMSTRONG FLIGHT RESEARCH CENTER


Allen Parker


Francisco Peña


Anthony Piazza

The Glenn Research Center (GRC) provided a broad spectrum of technical expertise in support of 15 NESC assessments and all of the NESC Technical Discipline Teams (TDT). These activities supported all mission directorates as well as several cross-cutting discipline activities. Significant GRC contributions this year were in support of the development of a strategy for broader integration of model-based systems engineering (MBSE) – a recent development in system-level modeling – throughout the Agency as well as support for compatibility of composite overwrapped pressure vessels with liquid oxygen. Deputies for the Propulsion, Electrical Power, Systems Engineering, and Nuclear Power and Propulsion TDTs are resident at GRC.

Developing a Roadmap for MBSE

At NASA for 28 years, Dr. Karen Weiland performs system engineering work at GRC for spaceflight projects. As the NESC Systems Engineering TDT Deputy for Strategy Integration, she has been developing a 5-year plan for MBSE development and infusion at NASA, along with an MBSE vision and roadmap for NASA and its major stakeholders.

"One component of the plan is the formation of a strategy group that will take a longer-term look at MBSE and NASA's use of it, identify desired systems engineering capabilities to advance, and recommend investments," she said. It also includes development of internal and external systems engineering-related funding sources, schedule, requirements, strategies, and activities.

Dr. Weiland supported the NASA Technical Fellow for Systems Engineering in 2016 as a NASA Headquarters Office of the Chief Engineer detailee, and was the lead for the NESC-sponsored MBSE Pathfinder. In 2017, she was the co-lead of the MBSE Pathfinder along with her strategic planning work. Dr. Weiland provides expertise on the scope of work, cadence, team progress, and integration of results into the NASA systems engineering workforce.

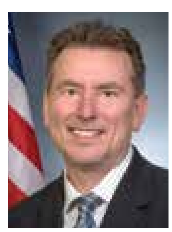
"My experience working with the NESC gives me an Agency-level perspective along with awareness and knowledge about how systems engineers across the Agency are organized and how they approach their work," she said. "I am able to share that perspective and knowledge directly with my peers and management. I also have an extensive network of colleagues at all the NASA Centers, industry, and academia that I use as resources, and I make connections among people to foster the growth of the user community at GRC and across the Agency."

Supporting an Agency-Wide Propulsion Community

As one of two deputies for the NASA Technical Fellow for Propulsion, Mr. Kevin Dickens helps to coordinate NESC propulsion-related activities at the Agency and GRC level. Mr. Dickens, the former European Service Module Propulsion sub-system manager, brings a wealth of experience in liquid propulsion. Also, he ensures the GRC aero propulsion, electric propulsion, and liquid propulsion capabilities are understood and can be leveraged by the broader NASA community as part of the propulsion capability leadership activities.

Mr. Dickens also supports propulsion-related assessments for the NESC including a recent effort to evaluate liquid apogee engine failures that have increased risk concerns for similar hardware used in multiple NASA missions. He was part of the NESC team that provided recommendations for engine screening and system design. "Several different liquid apogee engine issues arose within NASA and Air Force programs. The failures that occurred had many commonalities," said Mr. Dickens. "The NESC worked with each of the programs encountering these issues to understand the common threads between them and see if there were any cross-cutting issues."

He also participated in the 2017 Juno Check Valve Anomaly Recovery Assessment. The Juno spacecraft, which orbits Jupiter, had encountered problems with its propulsion system, and the NESC was asked to weigh in on the program's approach to conducting its remaining burns in order to continue with the science mission. "We evaluated whether there were any risks that should be considered," said Mr. Dickens, who enjoyed the opportunity to work on spacecraft for planetary exploration. "It was extremely far away and was a high-stakes problem," he said. "It's been interesting to get a wider view of the problems different programs are dealing with and finding the common threads that could benefit the propulsion community at large."



Robert S. Jankovsky
NESC Chief Engineer

52 GRC *employees supported NESC work in FY17*

GLENN RESEARCH CENTER

Dr. Karen Weiland

"My experience working with the NESC gives me an Agency-level perspective along with awareness and knowledge about how systems engineers across the Agency are organized and how they approach their work."

- DR. KAREN WEILAND
Systems Engineer, GRC

Kevin Dickens

The Goddard Space Flight Center (GSFC) continued to extensively support NESC activities in 2017. GSFC provided expertise to 16 Technical Discipline Teams with 57 engineers, technicians, and scientists. GSFC is the resident Center for the NASA Technical Fellows for Systems Engineering, Guidance, Navigation, and Control, Mechanical Systems, and Avionics. Significant contributions this year were in support of the Navy F/A-18 Fleet Physiological Events Assessment, automotive and non-automotive electrical, electronic, and electromechanical (EEE) parts testing, the Deep Space Climate Observatory CompHub Reset Assessment, analysis of a commercial crew provider's avionics system, and the Effects of Humidity on Dry Film Lubricant Storage and Performance Assessment.

Testing EEE Parts

In its assessment to perform EEE parts testing for the Commercial Crew Program (CCP), the NESC enlisted the help of the EEE Parts, Packaging, and Assembly Technologies Branch at GSFC. The work presents a new challenge from the typical selection, testing, and analysis of parts for NASA projects and programs, said Mr. Christopher Green, Associate Branch Head.

"We're performing hard evaluations of the commercial- and automotive-grade parts selected by CCP and its partners, including destructive physical analysis and environmental and electrical testing," he said. "Most of our in-house projects involve military standard parts so it has been interesting to see parts with which we haven't had experience. We are getting to use a different skill set in deprocessing these parts."

Working with CCP is relatively new for the branch, he said. "It's very interesting for us because there are a lot of new parts we haven't looked at before, as well as new manufacturers." Mr. Green's branch has been disassembling these parts to examine their internal elements, wire bonds, material interfaces, and the workmanship of the manufacturer. "We want to see how well they were manufactured, if the placement of wire bonds is correct, or if there are any defects that could lead to latent failure or reduced reliability," he said. "We identify any areas of concern where engineers may want to do further testing."

Mr. Green said he expects this trend of using commercial and automotive grade parts to continue and the NESC work "is a great way to hone our skills in processing these parts and build our knowledge base in preparation for new missions."

Analyzing Terabytes of Flight Data

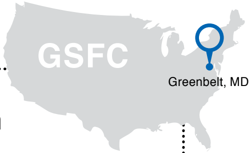
From her post at the NASA Wallops Flight Facility, Ms. Marta Shelton is pouring through data generated by the U.S. Navy's F/A-18 fleet as part of an assessment the NESC is conducting for Naval Air Systems Command. As part of GSFC's electrical engineering branch where her work includes optimizing antenna bandwidth for sounding rockets and calculating data rates for cube satellite missions, Ms. Shelton has enjoyed the challenge of the NESC work.

"It is incredibly fast paced," she said of the assessment. "The aircraft systems are extremely complex. There is a lot of information to assimilate in order to be successful," she said. "But that has also made it exciting and interesting."

Ms. Shelton is part of the assessment's data team studying the different data parameters recorded on the F/A-18. "There are more than 5,000 parameters that we are looking at to understand what role they play in the operations of the avionics, and particularly how they affect the environment of the crew in the cabin." She examined several terabytes of historical flight data, performed statistical analysis, and developed a cabin pressure model to aid engineering investigations.

"When I analyze data, I need to understand all of the systems and subsystems. It's given me the chance to learn as much as I can about the engineering design and how it integrates with the physiological side, which is a field that is new for me."

With an undergraduate degree in mathematics, Ms. Shelton is currently working on her master's degree in aerospace engineering. "This assessment has been a perfect match for me because I love math and statistics, which is a large aspect of the project. And I'm really impressed at the talent the NESC has available. Everyone I have worked with has been an expert in his or her field and has worked well together."



George L. Jackson
NESC Chief Engineer

57 GSFC *employees supported NESC work in FY17*

GODDARD SPACE FLIGHT CENTER

Christopher Green

Marta Shelton

"I'm really impressed at the talent the NESC has available. Everyone I have worked with has been an expert in his or her field and has worked well together."

- MARTA SHELTON
Aerospace Engineer, GSFC

The Jet Propulsion Laboratory (JPL) provided technical leadership and engineering expertise to 23 new or ongoing NESC assessments in 2017. JPL's expertise in composite overwrapped pressure vessels (COPV), avionics, software, environmental monitoring, mechanical structures, and model-based systems engineering (MBSE) supported assessments for both the Science and Human Exploration and Operations Mission Directorates. Significant contributions included qualification testing of an enhanced RAD750 Single-Board Computer (SBC), design of experiments to identify driving parameters leading to COPV rupture, Exploration Systems Development (ESD) Interface Verification and Validation (V&V), and characterization of materials compatibility data to substantiate the Orion Multi-Purpose Crew Vehicle (MPCV) bellows design. In addition, 50 JPL employees served on Technical Discipline Teams (TDT) working with NASA Technical Fellows on advancement of Agency engineering initiatives. JPL also provides leadership for the COPV Working Group and the Robotic Spaceflight TDT. The NESC Chief Scientist and Guidance, Navigation, and Control TDT deputy reside at JPL.

Perfecting the Art of Systems Engineering through Enhanced Integrated Systems Analysis

Mr. Marc Sarrel utilizes his expertise in systems engineering and software architectures to assist the NESC with assessments focused on analyzing cross-program integration. Using MBSE, he is assessing cross-program external interface integration and compliance between the Space Launch System (SLS), MPCV, and Ground Systems Development and Operations Programs.

"I have to decide how data is input and represented in the model as well as develop software," he said. He analyzes test beds and V&V plans across the programs to produce a report that integrates all of that multi-sourced data. "We integrate requirements, functions, and testing activities, which helps us analyze these plans for completeness." His MBSE work also includes analyzing providers' V&V plans for the Commercial Crew Program. He is also a part of an MBSE pathfinder effort, comparing resource utilization options for sending humans to Mars, which helps determine the trade-offs in each.

Mr. Sarrel enjoys the challenge of "translating our analysis from the world of algorithms into something managers and engineers can use."

Qualifying New Flight Computer

The Rad750 SBC, the flight computer used since 2002 on many NASA projects and spacecraft, recently began suffering the effects of age. This included the obsolescence of memory parts and problems associated with the design of the memory management unit (MMU). The obsolescence problem required a new board design to accommodate more advanced and readily available memory chips. The MMU issues had caused unexpected resets and would interfere with the implementation of new software architectures.

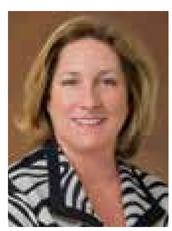
"Ultimately the root causes of the problems were identified and work-arounds were provided for on-going missions," said Mr. James Donaldson, Deputy Division 34 Chief Engineer. "But we needed funding to proceed with getting a new SBC board qualified that was faster and would address those problems."

"The Rad750 is similar to a laptop, but much more complex," added Mr. Jonathan Perret, Avionics Principal Engineer. "It runs the spacecraft with built-in features that make it recoverable in even the worst conditions. Its design and packaging make it tolerant to radiation, and its life expectancy is much longer than your average laptop," he said.

With NESC support, Mr. Perret and Mr. Donaldson assisted in the verification and testing of the manufacturer's redesign of the Rad750 in order to qualify it for flight use.

"We reviewed the design and testing of the unit in various environments to ensure it wouldn't fail during flight," said Mr. Perret, who organized the acquisition effort and interfaced with the computer's customers to understand their requirements. The work was a new challenge for him. "I previously worked on spacecraft radios, microcircuit engineering, and motor controllers, but had not yet worked on flight computers."

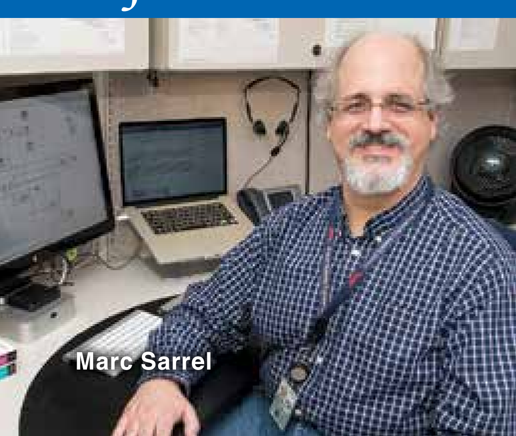
Mr. Donaldson spent time with the Rad750 manufacturer as part of the review team. "The processor chip, which includes the MMU, was redesigned and now runs faster than the previous version," he said. "It has greatly improved the product."



Kimberly A. Simpson
NESC Chief Engineer

81 JPL *employees supported NESC work in FY17*

JET PROPULSION LABORATORY



Marc Sarrel

> "I enjoy the challenge of translating our analysis from the world of algorithms into something managers and engineers can use."
>
> **- MARC SARREL**
> *Systems Engineer, JPL*

James Donaldson (L) and Jonathan Perret (R)

The Johnson Space Center (JSC) and the White Sands Test Facility (WSTF) 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 (MPCV) and 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 SLS aerosciences; Orion crew module heatshield molded Avcoat block bond verification; frangible joint designs; lithium-ion batteries thermal runaway; and F/A-18 physiological events. The NASA Technical Fellows for Environmental Control/Life Support and Passive Thermal resident at JSC joined with other Agency discipline leaders to strengthen technical community connections. They accomplished this through joint sponsorship and participation in activities such as the Structures, Loads, and Mechanical Systems Young Professionals Forum; the Thermal and Fluids Analysis Workshop; and Capability Leadership Teams to help define the future of NASA technical disciplines.

Analyzing Navy F/A-18 Physiological Events

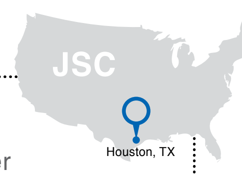
Dr. John Graf is a senior technology development engineer within JSC Engineering's Crew and Thermal Systems Division and has worked on a number of different NESC assessments during his career. From his first NESC assignment he was impressed with NESC's support of early career engineers and promotion of a "trust and respect" culture. Most recently Dr. Graf has been engaged in the Navy F/A-18 physiological events assessment where he worked to understand the complex interaction between the aircraft's oxygen delivery system and the flight crew, and he used this "trust and respect" culture to collaborate with other team members and develop a simple conceptual model to understand and explain this very complex relationship. According to Dr. Graf, because of this culture, "the conceptual model we developed together was better than anything we could have done individually, and it wouldn't have been possible without the tone and tenor Mr. [Ralph] Roe set in the [NESC's] beginning."

Modeling Material Fracture and Frangible Joints

Mr. Claude Bryant is a Senior Structural Analyst with Jacobs Technology and has brought his 30 years of finite element analysis and materials failure expertise to the modeling and understanding of frangible joint physics. Mr. Bryant began his work with a previously created frangible joint computational model and extended the underlying physics to represent other similar end-notch frangible joint designs, but quickly transitioned to material properties research and model development. Mr. Bryant used both his vast experience and tenacious research to understand and model the behavior of Al 7075-T7351 fracture properties and predict model responses to different lots of material under the extremely high strain rates experienced in frangible joints. While performing this high level work, he also mentored a junior structural analyst. When asked about his experience in the assessment Mr. Bryant said, "This is the third NESC team I have had the pleasure and privilege to be a member of. The collection of cross-disciplinary talent is always humbling. Everyone learns something about subjects outside of their expertise. I'm continually impressed by how NESC management ensures that all team members contribute meaningful work while meeting the project goals."

COPV Buckling and Fire Hazard

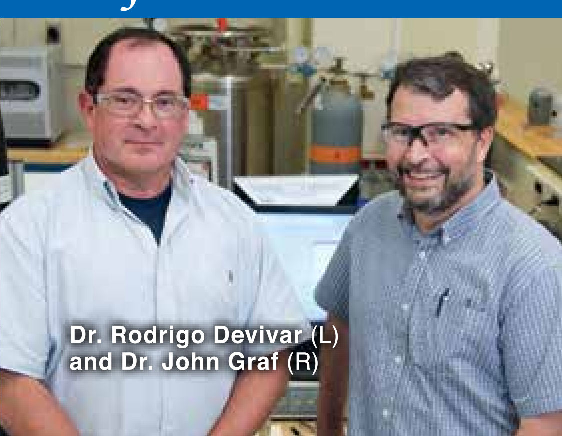
Mr. Steve Peralta is WSTF's Oxygen Compatibility Assessment Core Capability Project Manager, and has extensive experience in the oxygen compatibility of materials when exposed to enriched oxygen environments. He was tapped to investigate the SpaceX Falcon 9 carbon overwrapped pressure vessels (COPV) that contain helium, are immersed in sub-cooled liquid oxygen, and were suspected to be the cause of the Falcon 9 pad explosion during a static fire test. Mr. Peralta's team analyzed the COPV use, identified gaps in understanding, and executed testing to better understand the risks. He found that this particular application is much more complex than originally thought and helped bring to bear additional expertise to the problem. Mr. Peralta's efforts on this and other assessments have benefitted from the NESC's provision of statistics analysis expertise, which he says "have been invaluable in helping us with design of experiments for some of our oxygen tests and allowed us to move toward analyzing and applying data in much more valuable ways."

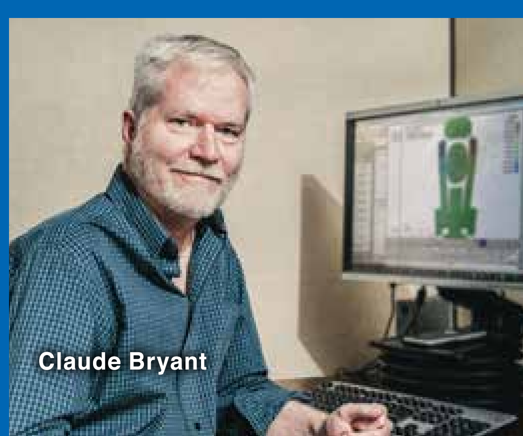


T. Scott West
NESC Chief Engineer

67 JSC *employees supported NESC work in FY17*

JOHNSON SPACE CENTER


Dr. Rodrigo Devivar (L) and Dr. John Graf (R)


Claude Bryant


Steve Peralta

The NESC was involved in numerous activities for programs at the Kennedy Space Center (KSC) including Commercial Crew Program (CCP) frangible joint testing and analysis; CCP composite overwrapped pressure vessel analysis; CCP entry, descent, and landing modeling; Ground Systems Development and Operations Orion crew module recovery sea condition dynamics, and Exploration Systems Development (ESD) modal test analysis. Likewise, KSC provided expertise to 20 different NESC activities, and also to multiple Technical Discipline Teams (TDT) in 2017. The NASA Technical Fellows for Electrical Power and Materials reside at KSC and rely on KSC expertise in many of their activities. KSC was engaged in a variety of NESC assessments including CCP frangible joint sensitivity testing; CCP propellant loading assessment; CCP electrical power systems review; ESD independent flight modeling; and non-linear slosh damping analysis for launch vehicles. The NESC also invested in KSC's electronics laboratory to work on Agency issues.

Leveraging Expertise in Structural Dynamics

"No matter how experienced you are in structural dynamics, you can always be surprised," said Dr. Ayman Abdallah, the Structural Dynamics Discipline Expert for the Launch Services Program (LSP) at KSC. LSP has managed for NASA the launch and selection of rockets for robotic missions since 1998. Dr. Abdallah, whose expertise includes loads and coupled loads analyses (CLA), said each mission is unique. "Each presents a problem that you want to solve to understand why you are seeing certain responses in the CLA."

As a member of the NESC's Loads and Dynamics TDT and CLA Discipline Guide, Dr. Abdallah lends his expertise to NESC assessments, most recently to help develop a fast CLA analysis. The new analysis method captures changes in payload finite element models without having to rerun the CLA to update the integrated system dynamic responses *(see page 51)*.

This ties in well with Dr. Abdallah's day-to-day work to analyze low frequency vibrations and the loads they generate on the launch vehicle and spacecraft. "We must make sure nothing breaks from vibrations you see at launch until the spacecraft separates in orbit," he said. Dr. Abdallah and the LSP Structural Loads Team simulate all critical flight events to determine spacecraft and launch vehicle responses to loads, which include accelerations, displacements, forces, and stress responses, performing at least three loads cycles prior to launch. "We conduct analyses early in the mission to provide design loads to the spacecraft program, another when designs are finalized, and a final verification loads cycle," he said. The analyses help provide independent verification and validation of the launch vehicle contractor's results.

Preserving Columbia's Legacy

Shortly after the loss of the Columbia Space Shuttle in 2003, the NESC was organized to help prevent another such tragedy from happening again. As the Apollo Challenger Columbia Lessons Learned Program (ACCLLP) Manager, Mr. Michael Ciannilli has been on a similar mission. The former NASA Test Director for shuttle launch and landing operations facilitates extensive lessons-learned tours and fields requests from researchers and academia who want to learn the lessons Columbia has to teach.

He spends his days among more than 84,000 artifacts from Columbia, housed in a 7,000-square-foot room in KSC's Vehicle Assembly Building. "I've spent years bringing people through this room and seeing the impact the story of Columbia and her crew has on our guests," said Mr. Ciannilli, who works to keep those lessons learned from getting lost to history. "As time moves on, connections to past events recede and lessons are no longer as effective as they could be to keep us from repeating mistakes. We want to bring back those lessons learned in innovative and effective ways." That includes tours offering a storytelling experience, having key people share experiences, providing artifacts to universities doing research in system failures, training courses, and working with the media to carry Columbia's message forward.

"The NESC has also collaborated with the ACCLLP through funding, and both organizations see great potential in continuing this partnership in the future," he said. "I view Columbia as still having a mission to perform — to change the future for the better," said Mr. Ciannilli. "We hope these stories help save lives and make other missions more successful."

Stephen A. Minute
NESC Chief Engineer

27 KSC *employees supported NESC work in FY17*

KENNEDY SPACE CENTER


Dr. Ayman Abdallah


Michael Ciannilli

"I view Columbia as still having a mission to perform — to change the future for the better. We hope these stories help save lives and make other missions more successful."

- MICHAEL CIANNILLI
ACCLLP Manager, KSC

The Langley Research Center (LaRC) continues to support the NESC mission to address the Agency's high risk programs and projects. LaRC engineers and scientists contributed wide-ranging technical expertise to lead and support multiple NESC assessments. The assessments reached across the Aeronautics Research, Human Exploration and Operations, Science, and the Space Technology Mission Directorates. LaRC supported all NESC Technical Discipline Teams, and is the host Center for the NESC Director's Office, Principal Engineers Office, NESC Integration Office, and the Management and Technical Support Office. The NASA Technical Fellows for Aerosciences, Flight Mechanics, Nondestructive Evaluation, Sensors and Instrumentation, and Software reside at LaRC.

Simulating Free Flight in the VST

Inside NASA's 20-Foot Vertical Spin Tunnel (VST), Ms. Vanessa Aubuchon set aloft scale models of SpaceX Dragon vehicles and the Orion Multi-Purpose Crew Vehicle (MPCV) in a variety of tests. The aerospace engineer was working on an NESC assessment in collaboration with SpaceX and the Commercial Crew Program to evaluate the dynamic stability characteristics of the Dragon vehicles.

"We're looking at cargo Dragon 1, which is flying to the International Space Station and the crewed version, Dragon 2, and comparing them against Orion crew module models," she said. The assessment will provide SpaceX with dynamic test data as well as advance NASA and industry's ability to predict dynamic capsule stability and flight performance.

"We've run several model configurations using different test techniques to determine the configuration effects on the dynamic stability of these capsules," said Ms. Aubuchon. "Since the capsules essentially fall through the atmosphere at the end of reentry, the vertical wind in the VST is perfect to simulate that."

Developing Innovative Test Designs

Dr. James Reeder's materials and structures expertise was leveraged for several NESC assessments in 2017 involving the MPCV Avcoat heatshield design and stress rupture studies for composite overwrapped pressure vessels (COPV).

As a research engineer, Dr. Reeder was instrumental in developing a special testing process to determine the root cause of cracks that developed during the Exploration Flight Test 1 (EFT-1) heatshield curing process. "We developed a special apparatus to allow us to control the strain levels on the test specimen as the temperature changed," said Dr. Reeder, "including innovative ways to control and filter strain signals coming from the test equipment." The heatshield was repaired and successfully flew on EFT-1.

He also helped design a test program to predict a certain failure mode in pressurized COPVs caused by stress rupture. Because testing numerous COPVs would be cost and time prohibitive, Dr. Reeder and the NESC team designed a process to test COPV strands, which allowed them to apply varying loads and extrapolate results equivalent to 10 years of stress.

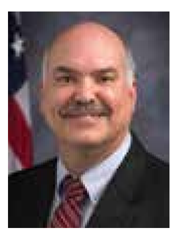
Dr. Reeder appreciates the NESC's emphasis on the technical work. "We can concentrate on figuring out the right answer, and that's wonderful," he said.

Modeling the SLS Flight Trajectory

An aerospace engineer working in advanced vehicle concept development, Mr. Paul Tartabini has been evaluating Mars reentry vehicles and other vehicle concepts for human missions to Mars. In a departure from this conceptual work, he has been assisting the NESC with the Exploration Systems Independent Modeling and Simulation Assessment.

"We are developing independent models and simulations focused on the Space Launch System (SLS). It's the most complex simulation I've ever worked on," he said. The simulation allows the NESC team to look at critical events in the SLS trajectory. Mr. Tartabini is the lead for the booster separation team. "We're performing clearance analysis of the booster separation from the core stage to ensure there is no recontact. Our NESC analysis provides verification and validation of the analysis done by the SLS Program," he said.

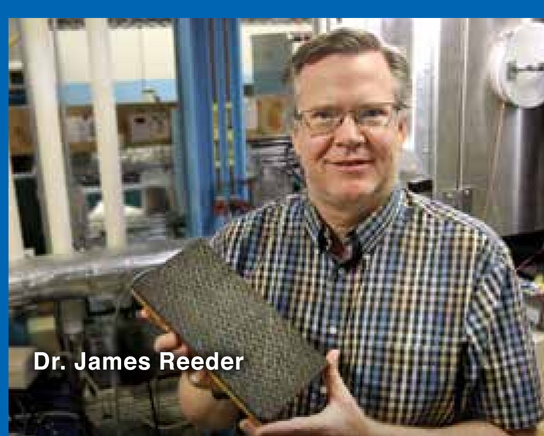
"Since the other part of my life is spent working on advanced concepts and systems analysis, it's helpful to have this knowledge of real flight vehicles. Our branch is always trying to bridge the gap between concept and flight."



Paul W. Roberts
NESC Chief Engineer

184 LaRC *employees supported NESC work in FY17*

LANGLEY RESEARCH CENTER



In 2017, the Marshall Space Flight Center (MSFC) provided engineer, scientist, and technician subject matter expert (SME) support to 27 NESC assessments, investigations, and special studies. These activities involved the areas of exploration systems development, space operations and environmental effects, science, and cross-cutting discipline activities. Some of the more significant efforts include: composite shell buckling, additive manufacturing, model-based systems engineering (MBSE), high temperature insulations, advanced chemical propulsion, modeling and simulation of complex launch vehicle/spacecraft interfaces, and human factors task analyses. The NASA Technical Fellows for Propulsion and Space Environments, and the Discipline and Capability Leader Deputies for the Human Factors, Nondestructive Evaluation, Propulsion, Nuclear Power and Propulsion, Software, and Space Environments Technical Discipline Teams (TDT) are resident at MSFC. MSFC provided critical facility and analytical support to numerous NESC investigations and all of the 21 NESC TDTs with more than 124 SMEs.

Human Factors TDT and Capability Leadership Support

Mr. Charlie Dischinger joined the MSFC Crew Systems Branch 23 years ago. He is a team lead in the Systems Analysis Branch and in 2010 was asked by Dr. Cynthia Null, the NASA Technical Fellow for Human Factors, to become her TDT discipline deputy. In 2015, that responsibility grew to include being the capability deputy for Human Factors.

In these capacities, he works with the NASA Technical Fellow for Human Factors to identify skills and knowledge needs for future exportation and aeronautical systems. The NESC has given him the opportunity to work with outstanding human factors specialists from across the Agency, and from other Government, academic, and commercial entities. This experience provides him with the opportunity to participate in and formulate technical assessments outside program-driven needs, and to be an advocate for human factors as the central design focus of NASA programs, at all levels of the Agency. A portion of these responsibilities in the past year include being the Agency representative to the ASTM International F47 Working Group on Commercial Spaceflight, participation in the annual Department of Defense Unmanned Systems Integration Workshop, and involvement in the Office of Safety and Mission Assurance-led human factors team supporting mishap investigations.

Systems Engineering TDT Support - MBSE Pathfinder Payload Adapter Team Lead

Mr. Terry Sanders has worked in space programs on two Spacelab missions, as an Operations Controller for the International Space Station, as a systems engineer on the first Material Science Research Rack, on the Constellation Program Ares-1 Upper Stage and Ares-5 designs, and currently on the Space Launch System (SLS) Program.

Mr. Sanders is participating in the second year of the NESC MBSE Pathfinder effort, which has a goal of growing the NASA MBSE user community. The Pathfinder effort is being used to find, develop, and promote MBSE best practices for NASA programs and projects, and to develop and implement an Agency-wide infrastructure for MBSE-related tools. Four teams are working on problems important to NASA, and Mr. Sanders leads the Payload Adapter Team. This team focused on alternate solutions for the SLS Block 1B Payload Adapter currently being designed. The SLS Block 1B will launch the first crewed mission of the Multi-Purpose Crew Vehicle.

The modeling effort was to create a system model in MagicDraw using the System Modeling Language (SysML), develop a user interface for added hardware, and create a three-dimensional model in Creo computer aided design software. This system model could be updated from SysML/MagicDraw model and then verified based on the Creo stress and loads analyses results.

The team stayed focused and were able to fulfill their major task requirements for the current year. This pathfinder effort has shown that the Agency systems engineer has another tool to use to tie together other models for a more complete, less ambiguous view of the system being designed. After all, "MBSE is really model-based engineering using systems engineering processes."

Steven J. Gentz
NESC Chief Engineer

124 MSFC *employees supported NESC work in FY17*

MARSHALL SPACE FLIGHT CENTER


Charlie Dischinger


Terry Sanders

> **"MBSE is really model-based engineering using systems engineering processes."**
>
> **- TERRY SANDERS**
> ***Systems Engineer, MSFC***

The Stennis Space Center (SSC) provided expert technical support to the NESC, including membership on the Assessment of Lead H2 Pop During SLS RS-25 Start effort. SSC has members on several NESC Technical Discipline Teams (TDT) including new members on the Avionics and Systems Engineering TDTs. SSC enabled the open exchange of ideas and collaborative decision-making by utilizing the unique locale, transportation capabilities, and cost effectiveness by hosting TDT yearly face-to-face meetings at SSC facilities and nearby Michoud Assembly Facility in New Orleans.

Modeling and Simulating Explosions

In an assessment to predict and evaluate the aeroacoustic loads induced by the rapid external combustion of hydrogen (H2) during the startup of the Space Launch System (SLS) main engines, the NESC enlisted the expertise of Dr. Daniel Allgood, who has developed a methodology for modeling propellant explosion events. The assessment follows a previous assessment in which Dr. Allgood provided his expertise to understanding the launch environments generated by SLS nozzle flow transient acoustics.

Dr. Allgood works in the Design and Analysis Division within the Engineering and Test Directorate at SSC and has spent the last 2 years modeling hydrogen and hydrocarbon detonations. In 2015, during another NESC assessment, Dr. Allgood modeled explosions to help predict potential damage to flight hardware in the Stennis E Test Complex. "We needed to understand the pressure waves generated from an explosion and how they would propagate through the test facility so that we could find ways to mitigate the effects," he said. Following that assessment, he was tasked with determining and validating a best methodology to model H2 explosions.

To develop that methodology, Dr. Allgood studied experimental tests done at universities and government laboratories, modeling those tests and using them to validate his simulations. "I wanted to make sure I could predict whether a detonation or explosion event would occur, what pressure would be generated as a function of distance from the source, and how it would interact with the surrounding structure."

His modeling approach was a success and has been used to validate a variety of explosion events contained within vessels or in open air. "As a result, I have been able to support some H2 explosion testing at our B Test Stand in support of the Space Launch System Program," he said. His modeling approach will be used during the NESC H2 assessment to help determine the loads generated on the engine, nozzle, and surrounding components should H2 be present at SLS engine start up.

"My graduate work was in modeling detonations," said Dr. Allgood. "It's nice to continue that same work."

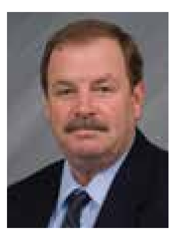
Cross-Agency Software Development

As a software engineer, Mr. Alex Elliot supports ground testing of space flight hardware to ensure a safe launch, which includes gathering physical sensor data for analysis as well as operationally testing flight control systems. Mr. Elliot brings his expertise to the Software TDT, which supports assessments for the NESC.

"Through the NESC and TDT, I have gained experience in Agency-level efforts to make software and hardware safer for use in critical missions while bringing SSC experience and lessons learned to the larger team," said Mr. Elliot.

Mr. Elliot meets with software experts from across the Agency to discuss software processes and how Agency standards are applied during software development. In his work with the NESC he has been instrumental in developing a software application that will be available across other Centers. "We're trying to make things accessible across Center boundaries," he said, which can be challenging as each Center may have different platforms and procedures regarding software requirements.

Working across NASA Centers also brings rewards, he added. "I like the opportunity to find out what is going on at other Centers, seeing the different data acquisition systems, and everything that is different from what I see day-to-day. You get a bigger picture view when you step outside of your own Center, your own comfort zone," he said. "You often find that many people deal with the same issues as you and sometimes they have better solutions. And it helps when you work on a multi-Center project to have a little of that outside Center knowledge."



Michael D. Smiles
NESC Chief Engineer

16 SSC *employees supported NESC work in FY17*

STENNIS SPACE CENTER


Dr. Daniel Allgood


Alex Elliot

> **"Through the NESC and TDT, I have gained experience in Agency-level efforts to make software and hardware safer for use in critical missions while bringing SSC experience and lessons learned to the larger team."**
>
> **- ALEX ELLIOT**
> ***Software Engineer, SSC***

NESC Knowledge Products

Capturing and Preserving Critical Knowledge for the Future

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 offers a wide variety of knowledge products that can be readily accessed from technical assessments reports to technical bulletins to video libraries.

NESC Technical Discipline Teams
nen.nasa.gov

Led by NASA Technical Fellows, provide the primary workforce for NESC assessments and support activities, and include communities of practice

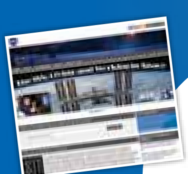
Technical Papers and Conference Proceedings

Written by members of the NESC and NESC Technical Discipline Teams (TDT) to capture and convey new knowledge learned on NESC assessments

Technical Bulletins

Critical knowledge captured from NESC assessments in the form of new engineering information or best practices in a one-page format

NESC Assessments and Support Activities
nesc.nasa.gov



Assessment Engineering Reports
ntrs.nasa.gov

The detailed engineering and analysis available as Technical Memorandums (TM)

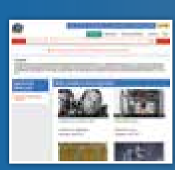
NESC Technical Update

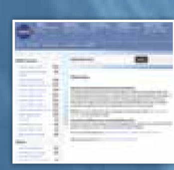
Annual summary of NESC assessment activities including lessons learned, technical bulletins, innovative techniques, discipline features, technical journal, and conference publications

Lessons Learned

Captured knowledge or understanding gained on NESC assessments that would benefit the work of others

NESC Academy:
Video library of 760+ informative lessons relevant to current NASA issues and challenges
nescacademy.nasa.gov





LLIS:
Agency-Level Lessons Learned Information System (LLIS)
llis.nasa.gov

Illustration of the Orion Multi-Purpose Crew Vehicle during Exploration Mission-1

NESC Academy:

Informative Lessons Relevant to Current NASA Issues and Challenges

The NESC Academy was established to enable effective knowledge capture and transfer, ensuring hard-won technical information remains accessible to NASA engineers.

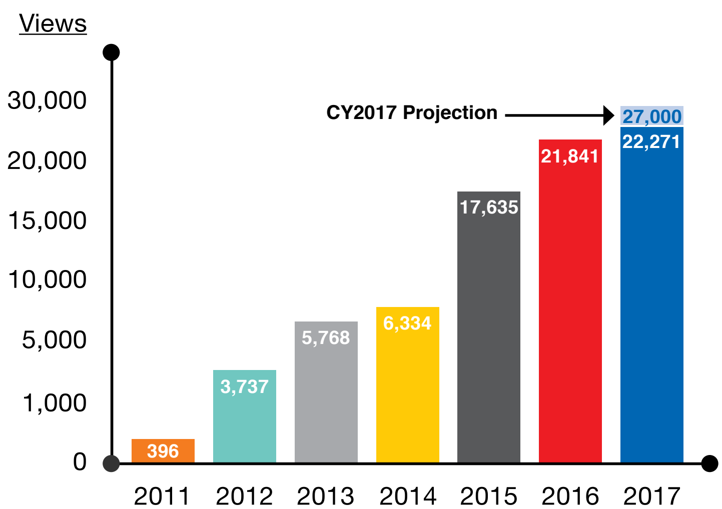
The NESC Academy presents live and on-demand content from researchers, engineers, and field experts in 21 technical disciplines relevant to the design, development, test, and operation of NASA programs and projects. It delivers more than 760 videos containing interviews, tutorials, lectures, and lessons learned in an engaging format that features side-by-side video and slides, powerful search capabilities, downloadable course materials, and more. Viewers can learn from NASA's senior scientists and engineers as well as recognized discipline experts from industry and academia.

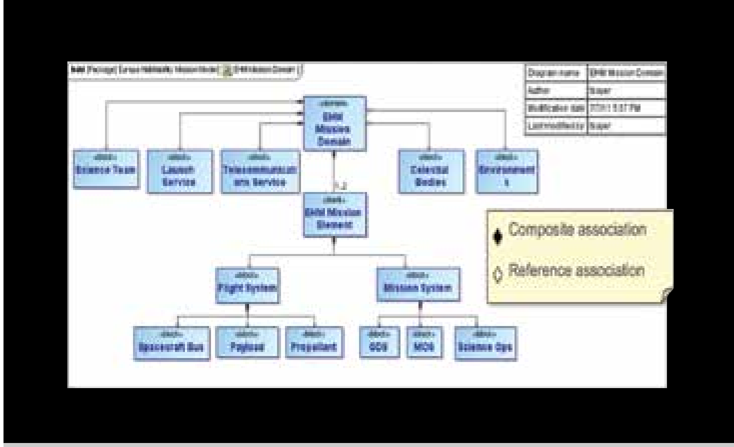
The NESC Academy offers the viewer a virtual, self-paced classroom experience based on a state-of-the-art video player for education, which enables dual video streams for content, typically one for the presenter and another for presentation materials. Desktop and mobile devices are supported.

A popular feature of the NESC Academy is live technical webcasts provided as a service to the discipline communities, which are archived for later viewing. Viewers can send in questions to the presenter during the broadcasts for two-way interaction. A total of 760 videos have been released as of September 2017.

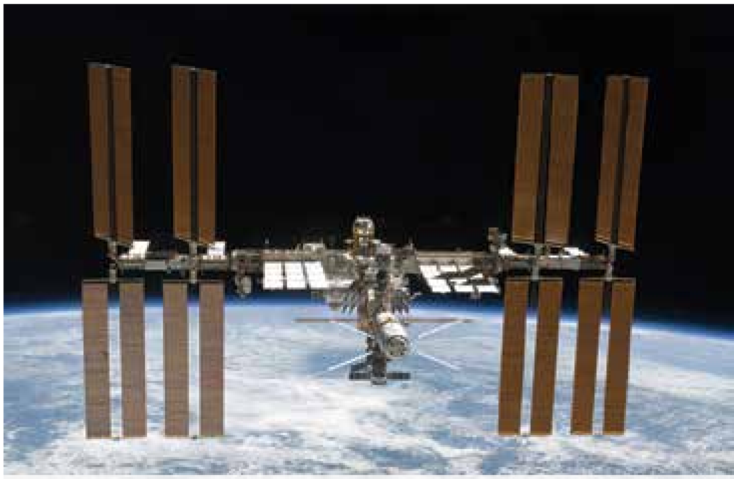
TOTAL PAGE VIEWS

as of September 2017





#1 **Systems Engineering**
Model-Centric Engineering, Part 1:
Introduction to Model-Based Systems Engineering



#3 **Human Factors**
Introduction to the International Space Station

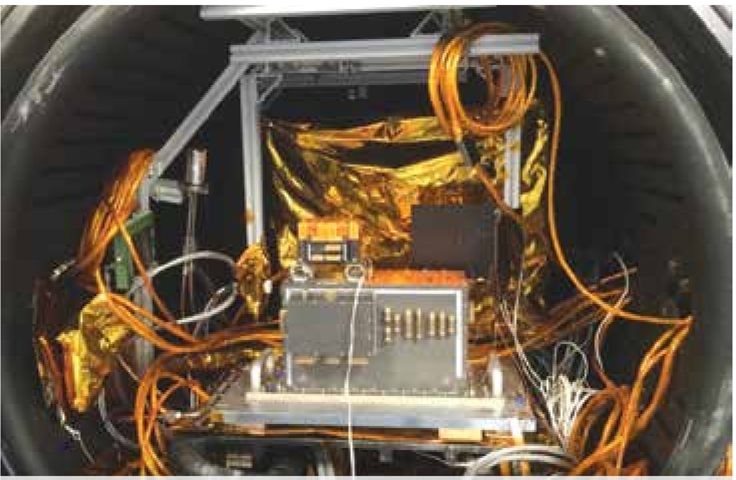
#5 **Guidance, Navigation, and Control**
Fundamentals of Spacecraft Control-Structure Interaction

NESC Academy videos have received

78,945+ VIEWS SINCE INCEPTION,

with more than 21,000 views in CY16 alone, and projections far exceed that number of views in CY17, illustrating the popularity of this approach among NESC Academy users.

Aerosciences
Lessons Learned on Past Manned Spaceflight Programs that Seem to Have Been Forgotten
#2



Passive Thermal
Common Thermal Modeling Mistakes, Part 1
#4

Passive Thermal
Short Course on Li-Ion Batteries: Fundamental Concepts, Heating Mechanisms and Simulation Techniques
#6

TOP 6 MOST VIEWED VIDEOS

January - September 2017

MOST VIEWED VIDEOS

By Discipline (January - September 2017)

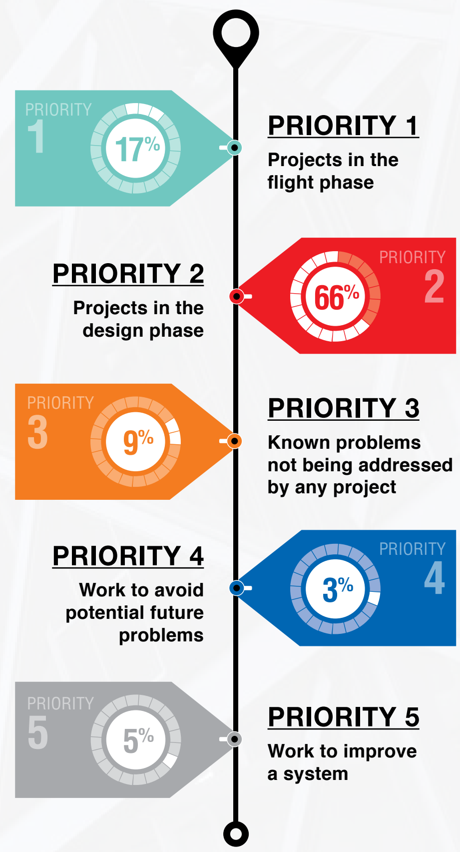
Aerosciences	Lessons Learned on Past Manned Spaceflight Programs that Seem to Have Been Forgotten
Avionics	Fundamentals of Electromagnetic Compatibility, Part 1 - Introduction
Electrical Power	Short Course on Li-Ion Batteries: Fundamental Concepts, Heating Mechanisms, and Simulation Techniques
Environmental Control/Life Support	Exploring Mars with the NASA Mars Science Laboratory Rover
Flight Mechanics	Standard Check-Cases for Six-Degree-of-Freedom Flight Vehicle Simulations
Guidance, Navigation, and Control	Fundamentals of Spacecraft Control-Structure Interaction
Human Factors	Introduction to the International Space Station
Loads and Dynamics	Shock and Vibration: 01. Natural Frequencies, Part 1
Materials	Selected Apollo and Shuttle Lessons Learned
Mechanical Systems	An Overview of Fastener Requirements in the New NASA-STD-5020
Nondestructive Evaluation	Introduction of Probability of Detection (POD) for Nondestructive Evaluation (NDE)
Passive Thermal	Common Thermal Modeling Mistakes, Part 1
Propulsion	Saturn Launch Vehicles: Engine Restart and Propellant Control in Zero-g
Sensors and Instrumentation	Nano Chem Sensors
Structures	Testing and Analysis of Advanced Composite Tow-Steered Shells
Systems Engineering	Model-Centric Engineering, Part 1: Introduction to Model-Based Systems Engineering
Other NESC	Creativity through Functional Abstraction

The NESC Academy video catalog is available at
nescacademy.nasa.gov

Assessment and Support Activities

The NESC conducts technical assessments or provides technical support in response to requests for assistance. The following pages present some of the technical activities completed in 2017, categorized by NESC Selection Priority.

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



In-Progress Requests for Technical Assessments and Support

Priority 1 Completed Assessments

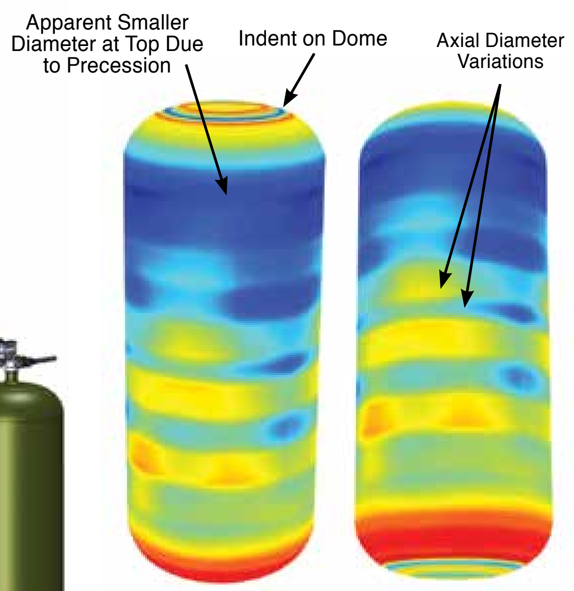
Technical Support of Projects in the Flight Phase

COPV Liner Inspection Capability Development

Composite overwrapped pressure vessels (COPV) are widely used in launch vehicles and spacecraft to hold pressurized liquids and gases. Reliable inspection methods are needed for human-rated programs. Following the failure of a COPV during a commercial launch vehicle on-pad engine test, the Materials and Components Laboratories Office at White Sands Test Facility requested the NESC develop and assess the capability of scanning eddy current nondestructive evaluation methods for COPV liner flaw detection. The industry standard methodology, dye penetrant, has limitations on the minimum flaw size that can be reliably detected. Through the assessment, the NESC was able to develop a modified multi-purpose nondestructive evaluation scanner that demonstrated effective capabilities for COPV liner thickness mapping, enhanced flaw detection, surface profilometry, and laser imaging.

This work was performed by LaRC, JSC, JPL, MSFC, and WSTF. NASA/TM-2016-219369

COPV Inspection Station



3D scans of lightweight liner

Deployed Solar Array Wing

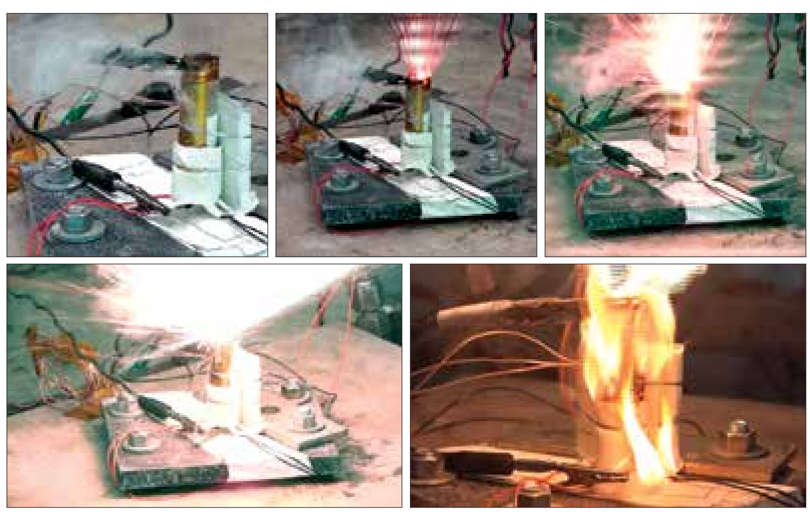
ISS Solar Array Wing Mast Shadowing

The International Space Station's (ISS) eight solar array wings provide primary power to run onboard systems and equipment. Each wing is made up of two photovoltaic blankets supported by a 105-foot-long mast that is deployable/retractable from a canister at the mast base. The mast is a complex folding mechanism composed of multiple longeron lattice structures. At certain attitudes, parts of the wing can cast a shadow on the mast or on a neighboring mast, causing an asymmetric thermally-induced strain on the longerons, potentially exceeding the mast limit load, resulting in longeron buckling. The NESC developed thermal and structural models of the solar array mast for use in on-orbit simulations that can improve understanding of mast performance and better inform ISS mission planning and operations. *This work was performed by LaRC, JPL, JSC, and MSFC.*

Mitigating the Severity of Li-Ion Battery Thermal Runaway

In the wake of a lithium-ion (Li-Ion) battery thermal runaway on Boeing's Dreamliner 787 aircraft, NASA assessed the small cell Li-Ion batteries used in Agency assets and updated its battery safety standard. The ISS Chief Engineer requested the NESC assess initiatives intended to reduce the severity/consequence of thermal runaway events within Li-Ion batteries used on the ISS. The NESC effort has helped Agency programs meet new requirements for flight battery designs by performing thermal analysis, testing, and design work to develop thermal runaway mitigation options for small cell Li-Ion batteries. New battery designs are now ready for deployment on the ISS.

This work was performed by KSC, ARC, GRC, GSFC, JSC, LaRC, and WSTF. NASA/TM-2017-219649



Example of induced thermal runaway in a Li-Ion battery.

SAFER Battery Assessment

During extravehicular activities (EVA), ISS astronauts wear a self-contained maneuvering unit called Simplified Aid for EVA Rescue (SAFER), that provides free-flying mobility to return to the ISS should they become free-floating. Used only in emergency situations, the backpacks use lithium-ion batteries, whose safety came into question following thermal runaway failures on commercial aircraft. The ISS Program Chief Engineer requested the NESC evaluate the SAFER battery against standards, lessons learned from the commercial failures, and other EVA battery redesigns. NESC tests and analyses resulted in suggestions for a future battery redesign to help mitigate thermal runaway risk.

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

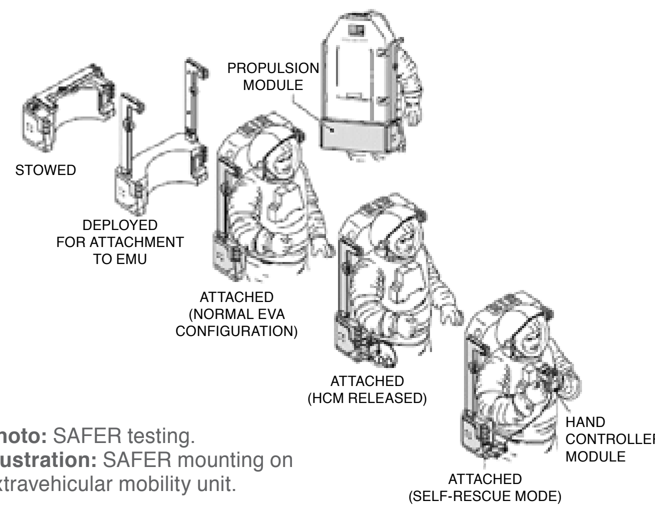


Photo: SAFER testing.
Illustration: SAFER mounting on extravehicular mobility unit.

Organizational Resilience in the ISS Program

The ISS is a multifaceted, complex combination of people and technology functioning as a sociotechnical system with a U.S. Operating Segment that is managed by the NASA ISS Program. The ISS Program is responsible for making risk-informed decisions for operations and safety in both flight and ground operations. An emerging approach to risk management, resilience engineering focuses on an organization's ability to continuously accommodate change and recognize subtle cues signaling impending disruptions, changes or pressures. To assist the ISS Program in identifying and reducing risks to their organizational resilience, the NESC Human Factors Technical Discipline Team examined the ISS Program against the principles of resilience engineering. The NESC team collected data from documents, observation of real time operations, and interviews with ISS personnel. The team provided recommendations intended to strengthen the adaptive capacity of the ISS Program.

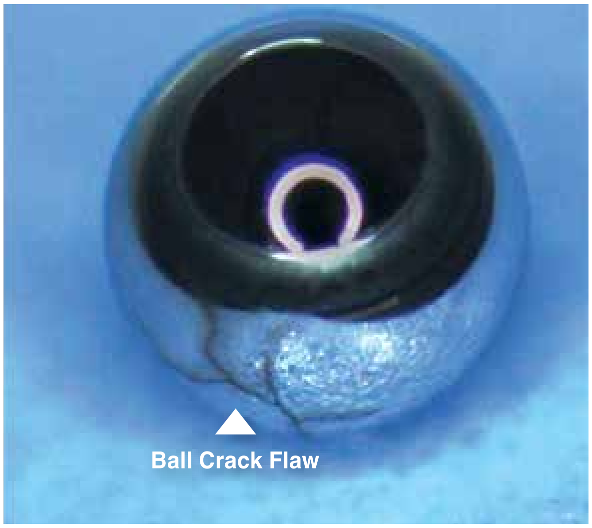
This work was performed by ARC, JSC, LaRC, and MSFC.

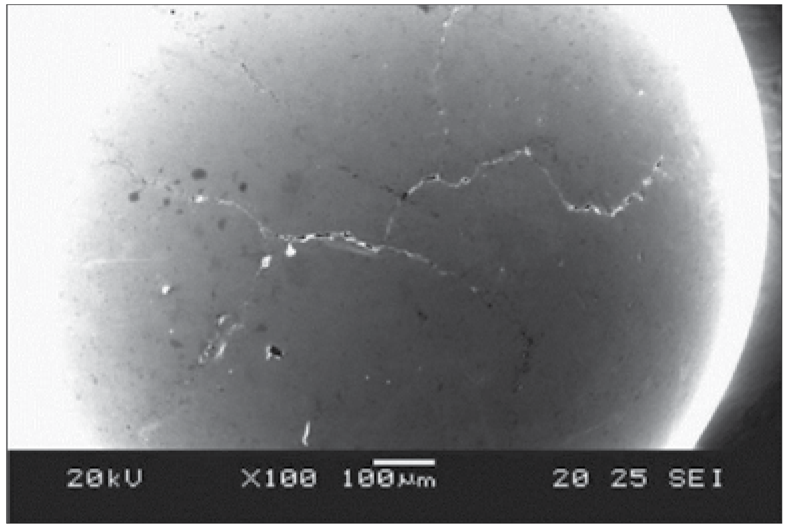
ISS Mission Control

Mitigating the Risk of Defective Bearing Balls

Center burst cracks are among many flaws that can impact the performance, operation, and life of a bearing's rolling element. The Science Mission Directorate was aware of potential bearing issues that could affect NASA missions. The NESC assembled a team of NASA and industry subject matter experts to examine all available test reports on defective bearing balls to determine the likelihood and associated risk to NASA programs and projects. The team concluded that only bearing balls with 100% inspections and full certifications should be used in NASA mission-critical mechanisms.

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





Example of a center burst crack material flaw created during the metal-forming process.

PRIORITY 1: COMPLETED SUPPORT ACTIVITIES

- Mars Organic Molecule Analyzer Wide Range Pump Qualification Model Failure Review Board Support
- Extravehicular Mobility Unit Water Pump Redesign
- NASA Docking System Non-Compliance Review
- Commercial Crew Program Failure Investigation Support

PRIORITY 1: WORK IN PROGRESS

In-Progress Assessments

- Human Spaceflight-1 Mishap Recurring Factor Study
- ISS/Extravehicular Activity Lithium-ion Battery Thermal Runaway Severity Reduction Measures
- Minimum Wear Life for the ISS Pump Control Valve Package Rotor Bearing System
- Multi-Purpose Oxygen Generators Swelling
- ISS Plasma Interaction Model Independent Review
- Express Logistics Carrier Reverse Capacitor Follow-on Testing
- Calorimetry for Lithium-ion Battery Thermal Runaway
- Deep Space Climate Observatory CompHub Reset Anomaly
- Juno Check Valve Anomaly-Recovery Assessment
- Validation of ISS Lithium-ion Main Battery's Thermal Runaway Mitigation Analysis and Design Features

In-Progress Support Activities

- Support to Launch Services Provider Hardware Re-Use Assessment
- Space Station Remote Manipulator System Latching End Effector Snare Cable Lubrication and Wire Breakage
- Rapid Slews for Lunar Reconnaissance Orbiter
- Chandra X-Ray Observatory Advanced Composition Explorer Real-Time Data Support

Priority 2 Completed Assessments

Technical Support of Projects in the Design Phase

Entry TPS MMOD Damage Risk and Mitigation for Crewed Vehicles

Possible damage by micrometeoroid and orbital debris (MMOD) to the thermal protection system (TPS) of ISS crewed visiting vehicles (VV) is becoming a concern. The TPS that is critical for safe reentry can be exposed to the MMOD flux for long durations while docked at the ISS. The NESC was requested to provide the ISS and Commercial Crew Programs with a high-level planning tool that could clarify the near-term capability and collaborative planning needed to more thoroughly understand and mitigate MMOD impact damage risk to TPS. The NESC Team reviewed space shuttle damage assessment capabilities and TPS lessons learned; ISS VV damage tolerance requirements; detection and inspection technologies, and TPS damage mitigation options. In addition, part of this effort was applicable to the Orion Multi-Purpose Crew Vehicle.

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

Visiting vehicles at ISS *(from top)*:

SpaceX Dragon 2 *(illustration)*

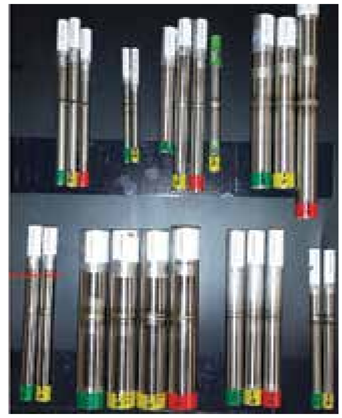
Boeing CST-100 Starliner *(illustration)*

Soyuz MS-03 crew ship

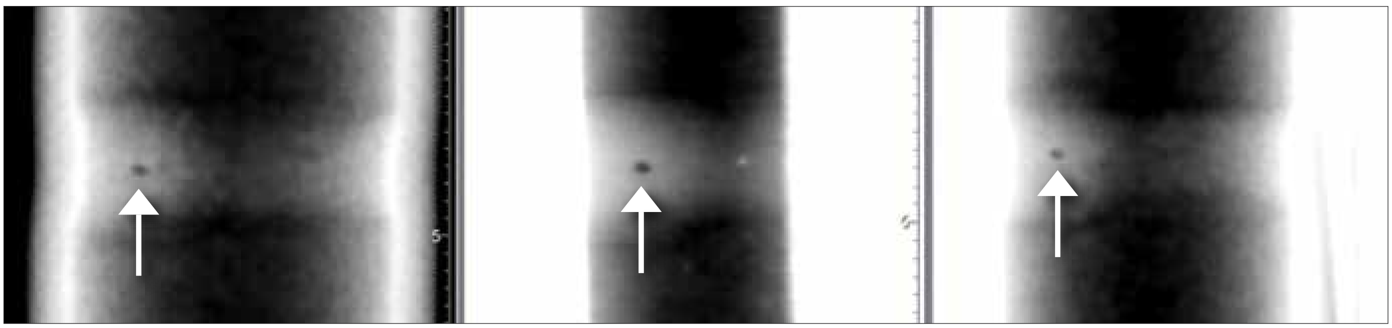
MPCV Crew Module Orbital Tube Weld Computed Radiography

Film radiography is currently used to inspect numerous tube welds on the Orion Multi-Purpose Crew Vehicle (MPCV). The film process requires substantial time and expense, thus the MPCV Chief Engineer requested the NESC assist in assessing the capability of computed radiography (CR) methods, which use equipment similar to conventional radiography, but replace film with resuable digital imaging plates. The assessment evaluated commercially available digital radiography systems using a representative set of tube-weld specimens with characterized real and simulated flaws. The NESC team recommended the use of CR for tube weld inspection.

This work was performed by LaRC, JSC, KSC, and MSFC.
NASA/TM-2016-219368



Samples of test tubes with circumferential welds that included various flaws.



X-ray Film | Computed Radiography | Digital Radiography

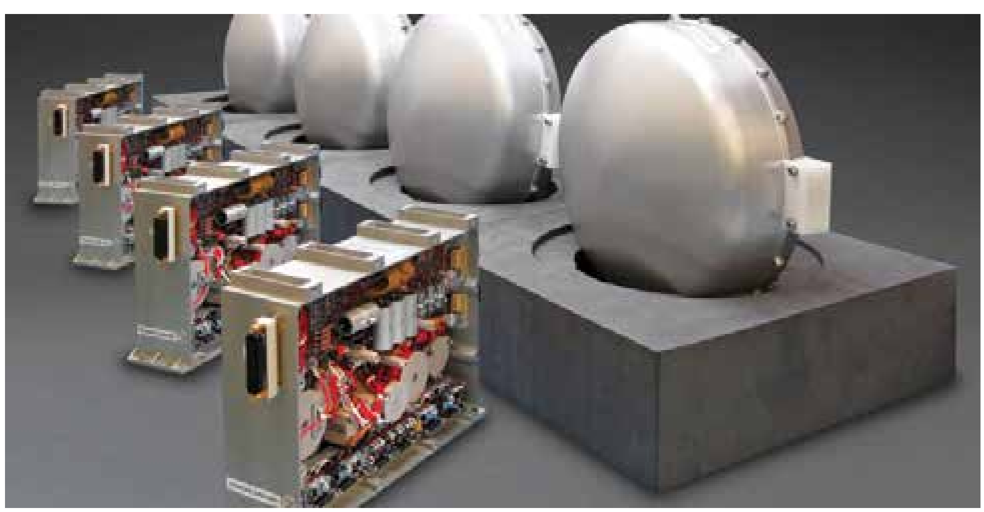
Detection of a pore in a tube weld using x-ray film, computed radiography, and digital radiography.

Reaction Wheel Performance for NASA Missions

Reaction wheels (RW) are widely used in civilian and military spacecraft to provide attitude control torque and momentum management functions. RWs rotate the spacecraft and are frequently used for stabilizing, slewing/orienting, and precision pointing spacecraft platforms. Typical RW actuators consist of a rotating inertia flywheel, a wheel suspension system (almost exclusively lubricated bearing balls), a wheel drive motor, and wheel drive electronics encased in a wheel housing/enclosure. Because their failure can severely compromise science data collection and reduce mission life, the NESC set out to identify best practices for promoting and maximizing RW life and study known wheel anomalies to better understand the failure modes.

This work was performed by GSFC and LaRC. NASA/TM-2017-219589

The Kepler Spacecraft relied on reaction wheels for precision pointing during its primary mission. *(illustration)*



Example of RW units and associated control electronics.
Photo Credit: *Bradford Engineering B.V.*

CCP Avionics Architecture Review

The Commercial Crew Program (CCP) Chief Engineer requested the NESC investigate the fault tolerance and redundancy of a CCP partner's proposed flight avionics systems architecture for crewed missions. The assessment's scope included validating the level of fault tolerance and redundancy of the flight avionics systems against CCP requirements, and identifying candidate electrical, electronic, and electromagnetic commercial off-the-shelf parts used for in-depth review.

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

Peer Review of Commercial Crew Aerodynamics Databases

As NASA's CCP partners continue development of their spacecraft and launch systems, CCP requested the NESC assess the approach, practices, and status of the development of a partner's aerodynamics databases, which predict vehicle aerodynamic performance through the flight envelope. The NESC team focused primarily on launch including aborts and entry, but the entire flight envelope was examined.

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

Spacecraft Electrical Power System Review

At the request of the CCP Chief Engineer, the NESC formed a team of Agency power specialists to evaluate the electrical power system design of a commercial partner's spacecraft. The team assessed the design against conventional NASA design practices, then assessed risks in areas of significant difference, which would better inform methodologies for future testing.

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

CCP V&V Integration and Mapping

To enhance its potential for mission success and reduce technical risk, the CCP requested the NESC perform an independent assessment of its commercial providers' verification and validation (V&V) flowdown, responses, and traceability of CCP requirements. The NESC Team reviewed the CCP-level planning approach, the partner's V&V planning responses, and the integration and flow of the V&V implementation between the two. Model-based systems engineering was used to identify any potential gaps or disconnects in the systems engineering approach.

This work was performed by GSFC, AFRC, JPL, JSC, KSC, and LaRC. NASA/TM-2017-219624

Assessing Risks of Frangible Joint Designs

To provide the CCP with confidence in the use of frangible joints (FJ) for human-rated launch vehicles and other human-rated applications, the NESC conducted an independent testing program of several end-notch FJ designs. The joints are typically used by NASA in the instantaneous separation of spacecraft structures such as launch vehicle stages and payload fairings. The multi-year assessment involved thorough testing of FJ assemblies, which yielded more than 100,000,000 records of test data due to the use of high-speed video and data acquisition. These data helped develop models that would assess the performance, sensitivities, and reliability of FJs. This investigation also resulted in the development of two innovative testing techniques, described on pages 44-47.

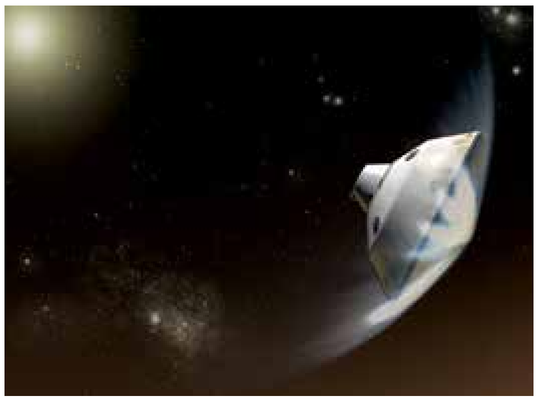
This work was performed by LaRC, KSC, AFRC, GSFC, JSC, MSFC, and WSTF.

Illustration of Commercial Crew Program Providers' Spacecraft: SpaceX Dragon 2 *(top)* and Boeing CST-100 Starliner *(bottom).*

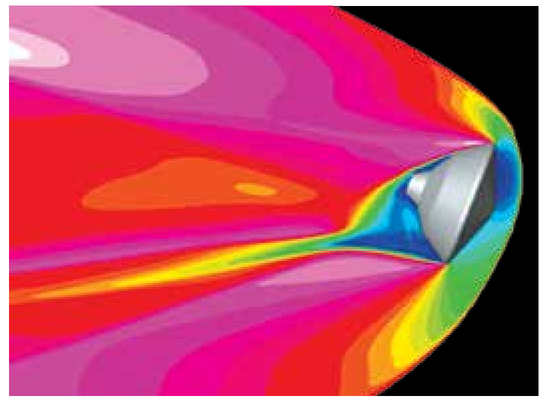
Assessment of the Mars 2020 Backshell Pressure Field for MEDLI 2

The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) Project will instrument the Mars 2020 aero backshell to record surface pressure data that could determine the backshell's contribution to the spacecraft's axial force coefficient during Mars entry. While available Viking wind tunnel data suggested a location for the single MEDLI2 pressure port, preliminary computational fluid dynamics (CFD) analysis indicated the location was not optimal in that it may not represent the pressure over the majority of backshell area. The MEDLI2 Project requested NESC assistance in determining optimal placement of a pressure transducer. The NESC team conducted a free-flight ballistic range test program using both scale models containing onboard pressure transducers and range instrumentation. Data products included measured backshell pressures. The data products also supported quantification of drag coefficient reconstruction uncertainties. Testing also supported investigation of blunt body separated wake flows in a near flight-like environment.

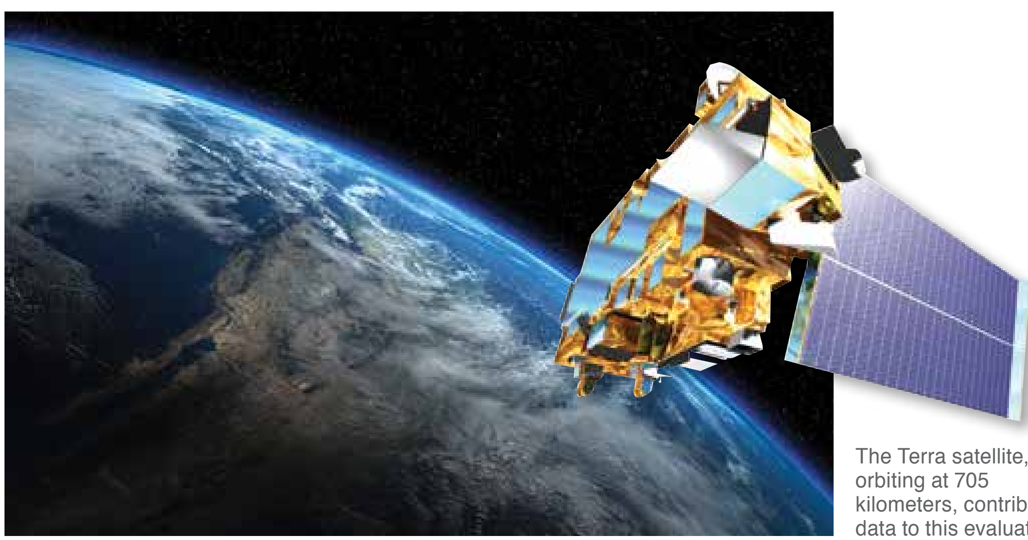
This work performed by LaRC, ARC, JPL, and JSC. NASA/ 2017-219666



Mars 2020 spacecraft at Mars entry. *(illustration)*



CFD solution of Mars entry.



The Terra satellite, orbiting at 705 kilometers, contributed data to this evaluation.

Evaluation of MMOD Risk Predictions with Available On-orbit Assets

The NESC evaluated the accuracy of NASA's MMOD risk modeling/assessment process used for robotic spacecraft in orbits higher than the ISS (above approximately 400 kilometers). To evaluate the entire MMOD risk assessment process at these altitudes, the NESC team compared satellite anomaly and failure data to the model-predicted risk. The NESC recognized several aspects of uncertainty in identifying spacecraft anomalies and documented recommendations to improve ongoing MMOD risk assessments.

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

Orion MPCV ascent abort concept. *(illustration)*

Independent Verification of Launch Abort Loads

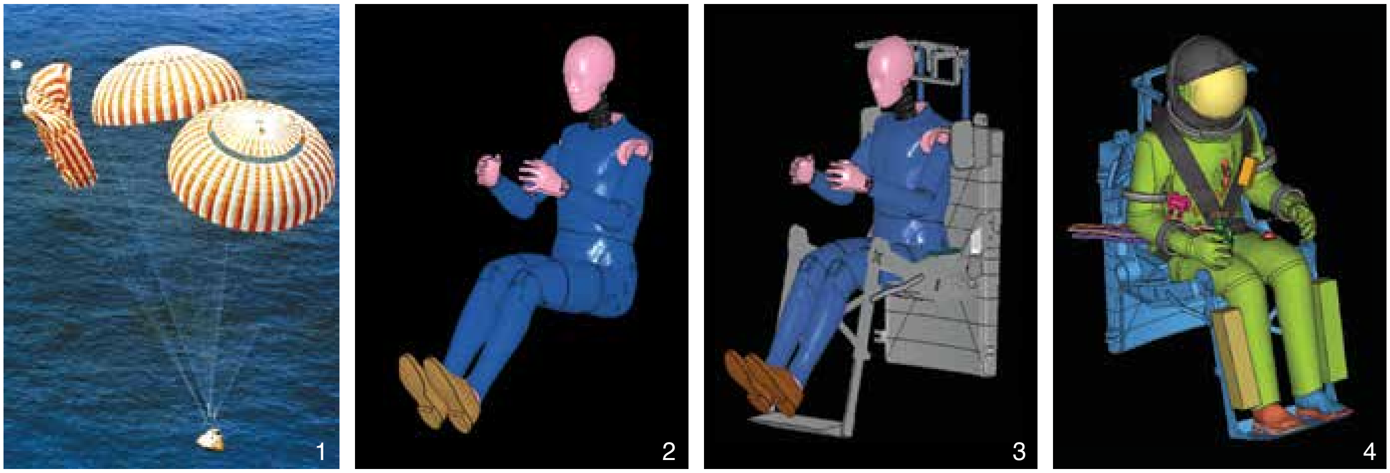
Large forces are placed on spacecraft and launch vehicle structures during a launch abort, especially those aborts occurring during the early ascent phase. Quantifying those forces is key to a design that maintains the structural integrity and functionality of the launch abort system, and helps to ensure the successful escape of the Orion crew module from danger. The NESC conducted an independent verification of the predicted ascent abort loads that would be induced on critical components of the launch abort vehicle over a range of off-nominal launch vehicle trajectories. Using an abort loads toolset developed under an earlier NESC assessment, the NESC was able to independently verify the pre-abort conditions and predict the abort loads, which were then compared to the Orion crew module contractor's predicted loads.

This work was performed by JSC and LaRC. NASA/TM-2017-219622

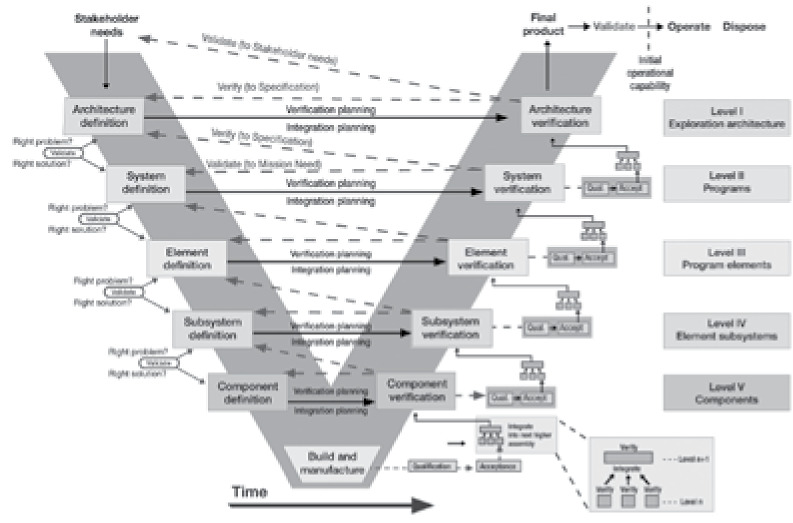
Analysis of ATD Response for Proposed Orion Crew Impact Attenuation System

Working with the Human Research Program at JSC, the NESC used anthropomorphic test devices (ATD), commonly referred to as crash test dummies, to help develop and validate finite element models (FEM) of both 5th-percentile female and 95th-percentile male ATDs for use in occupant protection analyses. A proposed design change to the Crew Impact Attenuation System (CIAS) in the Orion crew module (CM) prompted the analysis. Validated ATD FEMs were incorporated into FEMs of the CM seats, enabling modeling and simulation of human dynamic response in the current seat configuration and quantifying spacesuit-induced effects on ATD responses.

This work was performed by JSC, GRC, and LaRC. NASA/TM-2017-219657



Validated FEMs allow multiple CIAS configurations to be quickly evaluated. **1.** The Apollo command module crew seat attenuation system protected the crew against a single parachute failure, as will the Orion CM CIAS. **2.** Validated ATD FEM model. **3.** ATD FEM model integrated with crew seat FEM model. **4.** ATD with helmet integrated with crew seat.



Systems Engineering Life-Cycle "V" Model

ESD Verification and Validation Plan

The Exploration Systems Development (ESD) Program requested the NESC perform a review of the ESD V&V plan. The review objective was to help ensure that the cross-program integration approach over the Space Launch System (SLS), MPCV, and Ground Systems Development and Operations (GSDO) Programs would not result in gaps in ESD's V&V. In response, an NESC team evaluated ESD's V&V processes and documentation while another NESC team examined key interface requirements documents. Looking for gaps and areas of improvement, the first team examined ESD Program's planning and approach, including V&V facility availability and utilization plan fidelity; V&V schedule; critical technical areas; the V&V planning response for SLS, MPCV, and GSDO; and V&V implementation between ESD and the SLS/MPCV/GSDO organizations. The second team applied Model-Based Systems Engineering tools to model requirements flow-down and planning, looking for completeness and potential gaps or areas in need of improvement.

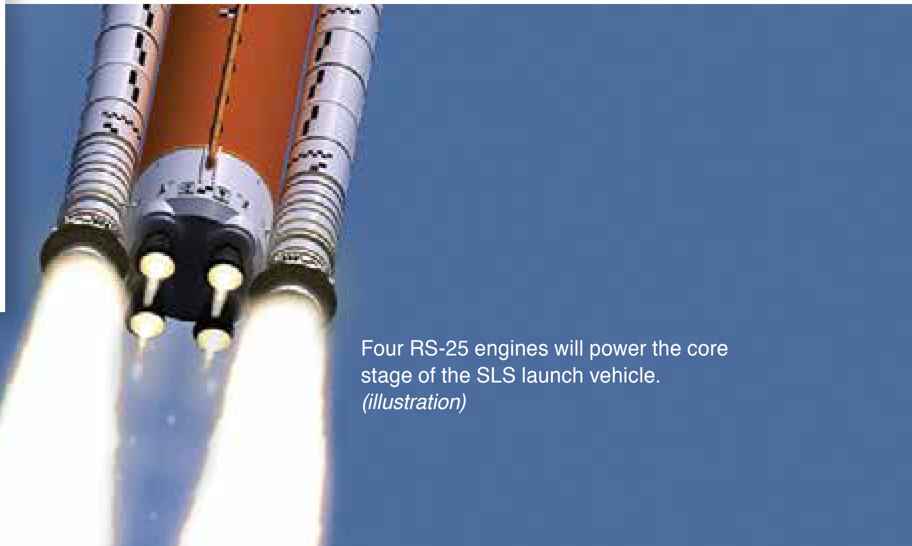
This work was performed by GSFC, AFRC, GRC, JPL, JSC, KSC, LaRC, and MSFC. NASA/TM-2017-219625

Refinement of Acoustics Design Load Specifications for RS-25 Nozzle Flow Transient

When the SLS four main RS-25 Space Shuttle heritage engines start, the aft end of the SLS will experience high acoustic loads. Components in this location must be able to withstand the start-up engine nozzle flow transient acoustic load environment. During a multi-year assessment, the NESC conducted both subscale and full-scale testing of the acoustic environments to obtain the data needed to help refine the load environment at critical component locations.

This work was performed by LaRC, MSFC, KSC, and SSC. NASA/TM-2017-219656

Test firing of an RS-25 engine in the A1 Test Stand at SSC.



Four RS-25 engines will power the core stage of the SLS launch vehicle. *(illustration)*

PRIORITY 2: COMPLETED SUPPORT ACTIVITIES

- Stratospheric Aerosol and Gas Experiment III Interface Adapter Module Subsystem Anomaly Investigation Support
- Space Launch System Vibroacoustics Plans and Analysis Support
- Alternative Orion Small Cell Battery Design
- Independent Review of Additive Manufacturing Development Plans
- James Webb Space Telescope Shaker Anomaly
- Commercial Crew Program Review of Nondestructive Evaluation of Additive Manufacturing
- Commercial Crew Program Turbopump Cracking Concern Support
- JPL Battery Failure Study
- Independent Peer Review of Ground Systems Design and Operations / Space Launch System Umbilical Modeling
- Potential Common-Cause Controller System Issues: Plumbrook Station Mechanical Vibration Facilities and Goddard Space Flight Center James Webb Space Telescope Systems
- Parachute Modeling Capability Gap Support
- European Service Module Structural Test Article Dynamic Model Correlation
- Space Launch System Flight Software Source Code Review
- Space Launch System Launch Vehicle Stage Adapter 2195 Cone Cracking Issue
- RS25 Thrust Oscillation in Coupled Loads Analysis and Fatigue Environments

PRIORITY 2: WORK IN PROGRESS

In-Progress Assessments

- Peer Review of the Multi-Purpose Crew Vehicle Aerodynamic/Aerothermal Database Models and Methods
- Launch Abort System Risk Mitigation
- Exploration Systems Independent Modeling and Simulation
- Space Launch System Aerosciences Independent Consultation and Review
- Independent Modeling and Simulation for Commercial Crew Program Entry, Descent, and Landing
- Evaluation/Validation of Range Safety BLAST Distance Focused Overpressure Model
- Human Factors Review of the Space Network Ground System Sustainment Project
- Multi-Purpose Crew Vehicle Avcoat Study
- Stress Ruptures Composite Overwrapped Pressure Vessel
- Composite Pressure Vessel Working Group
- Effects of Humidity on Dry Film Lubricant Storage and Performance
- Nonlinear Slosh Damping Analysis for Launch Vehicles
- Risk Reduction of Orion Government - Furnished Environmental Control and Life Support System
- Infrared Laser Sensor Technology Readiness and Maturation
- Application of System Identification to Parachute Modeling
- Orion Titanium Hydrazine Tank Weld - Sustain Load Cracking Issue
- Space Launch System Program Block I Booster Element Alternate Internal Insulation Risk Reduction
- Electrical, Electronic, Electromechanical Parts Testing for the Commercial Crew Program
- James Webb Space Telescope Space Environment Launch Constraints
- Static Software Analysis of the NASA Autonomous Flight Termination Software
- NESC Peer Review of Exploration Systems Development Integrated Vehicle Modal Test, Model Correlation, Development Flight Instrumentation and Flight Loads Readiness
- Parts-level vs. Board-level and Box-level Screening Testing
- Burst Factor Assessment for Pressure Vessels
- Commercial Crew Program Systems Engineering and Integration Processes
- NASA-Indian Research Organization Synthetic Aperture Radar Micrometeroid/ Orbital Debris Independent Assessment
- Independent Verification of Space Launch System Block 1 Pre-Launch, Liftoff, and Ascent Gust Methodology and Loads
- Commercial Crew Program Load and Go Assessment
- Space Launch System Liftoff Environment Models
- Evaluation of Occupant Protection Requirement Verification Approach by Commercial Crew Program Partners
- Viscous Effects on Launch Vehicle Ground Wind-Induced Oscillations
- Orion SIMULINK Guidance, Navigation, and Control Code Generation
- Commercial Crew Aerodynamics Peer Review
- Orion Simulator Risk Assessment
- Material Compatibility for Orion Propulsion Bellows
- Composite Overwrapped Pressure Vessel Densified Liquid Oxygen Compatibility Assessment
- Commercial Crew Program Capsule Dynamics in the NASA LaRC 20-Foot Vertical Spin Tunnel Assessment
- Full Independent Verification of Space Launch System Ascent Loads
- Human System Gap Analysis for Low Boom Supersonic X-Plane
- Space Launch System Pyro Firing Incident
- Assessment of Lead Hydrogen Pop During Space Launch System RS-25 Start
- Propellant Tank Safe-Life Analysis
- Agency Systemic Materials and Processes Issues
- Cross-Program Verification and Validation Integration and Mapping Assessment

In-Progress Support Activities

- Bond Verification Plan for Orion's Molded Avcoat Block Heatshield Design
- Commercial Crew Program Incremental Risk
- Ascent Abort-2 Independent Review Team
- B-2 Space Launch System Green Run Handling Processes
- European Service Module Major Propulsion Design Upgrades
- Electrical Power for High-Voltage Direct Current Battery Close-Call Investigation at Armstrong Flight Research Center
- Orion Crew Module Well Deck Recovery Conditions Dynamics Analysis
- Support for Space Launch System Design Certification Review
- Materials Technical Discipline Team Support for Orion Crew Module Uprighting System
- Accelerance Decoupling for Modal Test
- Design of Experiments Support for Commercial Crew Program Arc Jet Testing
- Affordable Vehicle Avionics Global Positioning System Testing Support
- Support in Conducting Atlas V Battery Hazard Test
- Space Launch System Integrated Spacecraft and Payload Element Modal Test Assistance
- Orion Propellant Gauging
- ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station Vibe Failure Review Board Support
- Analysis and Test of Space Launch System Core and Booster Stage Flight Termination System Batteries
- NOVICE Support to Launch Services Provider and Commercial Crew Program Radiation Assessment
- Orion Crew Module/Service Module Separation Bolt Life issue
- Office of Safety and Mission Assurance Safety Critical Material Control Audit
- Report on the workshop "Dust in the Atmosphere of Mars and Its Impact on Human Exploration"
- Commercial Crew Program Request for Pyroshock Support
- Nondestructive Support for Space Launch System Weld Anomalies
- Space Launch System Block 1B Guidance, Navigation, and Control Design Review
- Support for Evaluation of Space Launch System Program Polarity Testing Approach
- International Space Station Research Activities Outside the Microgravity Science Glovebox
- Commercial Crew Program Loads and Dynamics Test Support
- European Service Module Structural Test Article Dynamic Model Correlation

Priority 3:
Known Problems Not Being Addressed by Any Project

Completed Support Activities

- Development of Softgoods Design Factors of Safety Support

In-Progress Assessments

- Shell Buckling Knockdown Factor Proposal
- Rad750 Qualification Testing
- Implementation of JR-A Methodology into the NASGRO/FADD Codes to Improve Crack Instability Analysis
- Micrometeoroid/Orbital Debris Pressure Vessel Failure Criteria
- CubeSat Radiation Environments and ISS Radiation Dose Data
- Replacement Material Evaluation for Kalrez 1045 Spacecraft Propulsion Component Seals
- Composite Overwrapped Pressure Vessel Life Test
- Space Weather Architecture
- Safe, High Power Lithium-ion Battery Module Design

In-Progress Support Activities

- Additive Manufacturing Structural Integrity Initiative Project Oversight and Support

Priority 4:
Work to Avoid Potential Future Problems

Completed Support Activities

- Peer Review on Wind Induced Oscillation

In-Progress Assessments

- Space Weather Action Plan Extreme Surface/Internal Charging Environment Benchmarks

In-Progress Support Activities

- Peregrine Sounding Rocket Redesign
- Additive Manufactured Fuel Turbopump Disassembly/Inspection and Post-Test Data Evaluation
- Fluid Structure Interaction in Prediction of Parachute Performance

Priority 5:
Work to Improve a System

Completed Support Activities

- Review of Dynamic Power Convertor Proposals

In-Progress Assessments

- Empirical Launch Vehicle Explosion Model Evaluation
- Fast Coupled Loads Analysis via Norton-Thevenin Receptance Coupling
- Improved Design and Optimization of Complex Trajectories
- Demonstration of Integrated Electronic Technical Manuals to Support Ground Systems Operations
- Radiation Single Event Effects Impact on Complex Avionics Architecture Reliability

In-Progress Support Activities

- Fracture Control Standard and Handbook (NASA-STD-5019A)

Discipline Focus

Discipline Perspectives Related to Assessments

Perspectives on the NESC

from Former Astronaut, Nancy Currie-Gregg

In late 2017 Dr. Nancy Currie-Gregg retired from her position as an NESC Principal Engineer to embark on a new career in academia. After 30 years with the Agency, she joined the staff at Texas A&M University, where she's currently teaching the next generation of engineers, some of whom could one day end up at NASA. She has a lot to teach them.

A retired Army Colonel and aviator, Dr. Currie-Gregg joined NASA in 1987. She was selected as an astronaut and flew four Shuttle missions, including the first International Space Station assembly mission in 1998. A full career already behind her, she contemplated leaving NASA after her last flight in 2002, but shortly thereafter NASA lost the Space Shuttle Columbia and Dr. Currie-Gregg's plans changed.

"Following Columbia I felt compelled to remain at NASA to assist the Agency in determining what caused the accident and to contribute to the Space Shuttle Program return to flight (RTF) efforts in order to complete the construction of the International Space Station," she said. "It was important to the Agency and to me personally to see the Space Station fully assembled, as successfully and as safely as possible."

Dr. Currie-Gregg knew it could be a year or more before another shuttle mission was launched, so she looked for ways to help the Agency from an engineering perspective to return the Shuttle to flight. At that time there was a significant number of astronauts who had not flown a single flight, so she embarked on a mission to develop a cadre of people who could explain, in engineering terms, what it was like to work in a zero-g environment. "You can train. You can study. But until you've experienced spaceflight, you don't completely understand what living and working in a microgravity environment is like."

She was eventually selected to lead the Space Shuttle Program Safety and Mission Assurance Office. "It was the toughest job I've had during my tenure at NASA – much tougher than astronaut training and spaceflight. I was responsible for telling the astronauts, their families, and NASA that shuttle was safe enough to fly." It wasn't lost on her that she was putting lives on the line if she was wrong.

While Dr. Currie-Gregg worked shuttle safety issues for RTF, the concept of the NESC was being established. It grew out of the Columbia Accident Investigation Board (CAIB), which saw the need for an independent organization that could provide Agency programs with an independent perspective on difficult technical problems. She remembers when its new Director, Mr. Ralph Roe, Jr., now the NASA Chief Engineer, came to JSC. "He told us what the NESC was, its mission and its goals. When I heard about that, I said, 'when I grow up, I want to be in the NESC.'"

At that time she felt she wasn't qualified to join, at least not yet. "I had time in the Agency but hadn't served much time in engineering. Being a spacecraft operator doesn't make you an excellent engineer. I felt like I needed to work my way up to that." By 2007, after serving in her latest post as the Deputy Director of JSC's Engineering Directorate, she joined the NESC and would go on to serve 10 years, first as the NESC JSC Chief Engineer and then as a Principal Engineer, the well-established technical and managerial talent who lead the NESC's largest technical assessments.

As Dr. Currie-Gregg neared her retirement date, she spoke passionately about the NESC and its mission, which she said has never wavered. "In my mind it has fulfilled exactly the mission it was given by the CAIB and continues to do that every single day, for the Commercial Crew Program, Orion, and our science missions. Whether you are an astronaut, or an engineer in the trenches, or a safety person, you can turn to the NESC and get an exceptional assessment done by the best and brightest engineers and scientists in the Agency and nation," she said.

"It's a critical role. We will never know how many times the NESC has influenced a decision that may have prevented an accident. A friend of mine once said that we may have another accident in the future, but what we can't have is another accident because we didn't fully understand the risk. In this business we always have to accept some level of risk, but we need to do it with eyes wide open. The NESC mission is to properly characterize risk for NASA programs, senior management, and the astronauts," she said. "I flew with people who didn't completely understand the risk they were accepting when they launched into space."

When Dr. Currie-Gregg joined NASA in 1987, following the Challenger accident, everyone was focused on a safe RTF. But time and distance can dampen resolve and attention to risk. "In essence, you become a victim of your own success. After many years of operating the Space Shuttle without another accident, folks start to believe the risk is not as high as safety analysis indicates. I personally witnessed cognizance of the inherent risk of human spaceflight erode over time within the Space Shuttle community." Then Columbia happened, and that risk was understood in unimaginable ways.

In her role at the NESC, Dr. Currie-Gregg was focused on preventing another such tragedy. She worked on many assessments over the next decade, but two stand out for her – where she feels she made real and lasting contributions to the safety of human spaceflight.

She led an assessment of the Orion crew module (CM) heatshield to determine the root cause of issues that occurred during manufacturing of the Exploration Flight Test 1 heatshield. "Assisting the team in developing a comprehensive fault tree to guide our investigation, reviewing a multitude of manufacturing records, talking directly to personnel at the manufacturing plant, and conducting independent testing and analysis in order to finally discover the proximate causes of the issues was remarkable," she said. "The process we followed was indicative of the NESC's strength to draw on the capabilities of the Agency's best and brightest, as well as any additional expertise we required from academia, industry, and other government agencies."

She made great strides in spacecraft occupant protection as well, using Anthropomorphic Test Dummies (ATD) like those used in the automotive domain to develop safety standards for the Orion CM and NASA's commercial providers' vehicles. "We worked with experts from diverse areas such as NASCAR, the military services, the Federal Aviation Administration, and academia to create biodynamic models and simulations, test various ATDs, and develop spacecraft occupant protection standards and requirements to ensure the safety of future crews. I will walk away knowing that if I can help prevent an injury to a crew member, then I will have made a significant contribution to the future of spaceflight."

Upon her departure to teach at Texas A&M, she hoped the NESC would continue its mission. "I want the NESC to keep doing exactly what they have been doing: to keep continually questioning, to keep being the organization that is never satisfied with an answer that doesn't have the proper data, analysis, or technical rigor to back it up. It's been 14 years since the Columbia accident. By nature, the heightened sense of awareness of the risk associated with spaceflight erodes over time. The NESC must continue to be the voice in the room, challenging engineers and program personnel, asking 'Is this safe? Do you have the data to back up that statement?' While there is certainly risk associated with our science missions – primarily cost and schedule risks – the risk of human spaceflight is ultimately borne by someone's mom, dad, sibling, or child."

Dr. Currie-Gregg said she hoped to continue to have some affiliation with the NESC after she left. "It's a stellar organization," she said. "When people ask what I do for a living, I say I'm an engineer with the NESC – and in a former life was an astronaut too."

"IN THIS BUSINESS WE ALWAYS HAVE TO ACCEPT SOME LEVEL OF RISK, BUT WE NEED TO DO IT **WITH EYES WIDE OPEN**."

Photos (*left to right):* Currie-Gregg attired in a training version of the shuttle launch and entry garment at the Neutral Buoyancy Laboratory near JSC.

Prototype of a molded Avcoat block heatshield for the Orion Crew Module.

Currie-Gregg, STS109 Mission Specialist, works the controls for Columbia's robotic arm to maneuver crewmates during a Hubble Space Telescope servicing mission.

Be the Super Engineer that NASA Needs

Parting Words from Dr. Curtis Larsen

Interview with Dr. Curtis Larsen, former NASA Technical Fellow for Loads and Dynamics, conducted a few weeks prior to his retirement from NASA in August 2017.

When Dr. Curtis Larsen joined the NESC as the NASA Technical Fellow for Loads and Dynamics (L&D) in late 2005, he was attracted to the overall "problem solving nature" of the organization. "That's a natural for an engineer," he said, having spent several years in industry working as a forensics engineer, analyzing engineering failures to figure out what caused them. The NESC was offering a similar line of work, with the added challenge that space brings to the equation. "It was a chance to dig into the whole NASA-wide variety of issues and be a part of the team that goes after the solution and finds it. That held the promise of not being mundane and boring."

For Dr. Larsen, that promise was kept. He spent more than half of his NASA engineering career with the NESC, working with his L&D Technical Discipline Team (TDT) on a variety of assessments involving Constellation, Ares-1X, Space Shuttle, International Space Station, the Mars Science Laboratory, Orion, and more – solving acoustic, vibration, oscillation, and all manner of loads and dynamics issues, and in all aspects of flight, from the launch pad to landing.

Most recently Dr. Larsen and the TDT participated in an ongoing peer review of the Multi-Purpose Crew Vehicle, Space Launch System, and the Ground Systems Development and Operations Programs. "We contributed a lot to the loads and dynamics and structures success of those programs," he said, including approaches to integrated modal tests, roll out tests during the move to the launch pad, and the water landing and retrieval of the Orion crew module.

This variety of work and the opportunity to work with the nationally and internationally recognized experts who make up the TDT is what Dr. Larsen said he would miss most as he left the Agency and the NESC in late 2017. Dr. Larsen was embarking on a new teaching career with the aim of imparting a little hard-won wisdom and knowledge to those just starting out on a career journey he began more than 35 years ago.

Bridging that generational gap is vital to the next generation of engineers, he said. Dr. Larsen joined NASA when it was in the midst of a hiring boom for the Space Shuttle Program. "Most of us were early in our careers with only 5 to 10 years of experience. The rest were graybeards with very few in the mid-career range. I see the same thing today. We're tooling up for new programs and have hired new people, but there's still a gap in the middle. The graybeards are retiring and my generation did not do enough to capture that knowledge from them."

For NASA, whose projects are large, complex, and not mass produced, the generational gap can be particularly challenging, especially as the next vehicle to carry astronauts to space, Orion, takes shape. "As an Agency, we haven't done this kind of spacecraft hardware design and development since Shuttle was developed in the 1970s. That was a couple of engineering generations ago."

It's a demographic problem his own discipline has grappled with and why Dr. Larsen helped organize the NASA Structures, Loads and Dynamics, and Mechanical Systems (SLaMS) young professional workshops that he hoped would turn that tide. The forum provides younger engineers the opportunity to present their work to peers and seasoned technical experts across NASA. The annual forum reached its 6th anniversary in 2017. "They do a great job of connecting the older generation to the younger engineers and help guide that enthusiasm they have."

But while the discipline's demographic makeup hasn't changed, technology has skyrocketed. Computers and software have gotten better and faster, but the discipline and NASA at large have developed a greater dependency on them. "We rely too much on analysis and not tests. You have to have tests to anchor the analysis. The software can produce really pretty color pictures that look like the vehicle we're designing, but looking good doesn't equate to accuracy. That's the biggest challenge for the discipline, to re-instill that balance between test and analysis."

As the fall of 2017 approached, Dr. Larsen began his new adventure in academics. But before he left, he offered this nugget of wisdom to the early career engineers he left behind to carry on the L&D discipline. "Learn your analysis and learn the classics so you have another method to test your analyses. And get out to the hardware as much as you can to see it, touch it, and know what's going on with it. And get as much testing experience as you can. Then you'll be the super engineer that NASA needs."

Dr. Christopher Iannello
NASA Technical Fellow
for Electrical Power

Lithium-ion Battery Risk Mitigation Efforts Continue

When Boeing's Dreamliner 787 aircraft suffered a lithium-ion (Li-Ion) battery thermal runaway (TR), it sparked an effort at NASA to reevaluate the Li-Ion batteries the Agency uses in spaceflight and onboard assets like the International Space Station (ISS). Though NASA had not experienced any issues, the Agency updated its battery safety standard with new requirements for flight battery designs and identified the need for low-cost options for reducing TR severity.

To help Agency programs and projects meet these new requirements and to examine the Li-Ion battery designs in development for ISS, Dr. Christopher Iannello, NASA Technical Fellow for Electrical Power, assembled battery experts from across NASA and industry for an NESC assessment.

After extensive thermal analysis and testing by the Passive Thermal Team, led by the NASA Technical Fellow for Passive Thermal, the assessment team developed several ways to modify the design to mitigate TR risk in small cell Li-Ion batteries, like those used by astronauts during extravehicular activities (EVA). Those changes are now being incorporated at NASA and are generating interest from the industry at large.

Rules of Design

Bringing knowledge gained from the NESC-sponsored development pathfinder, Dr. Eric Darcy from the Electrical Power Technical Discipline Team and the NESC Team established five "design rules" that when employed can keep cell failures from propagating.

"Once a cell inside a Li-Ion battery pack fails, the key is to keep that failure from propagating to its neighbors and causing a TR," said Dr. Iannello. These rules address key mitigation strategies, from allowing adequate cell spacing to managing heat distribution with interstitial materials. For example, "If an individual cell heats up, you need to distribute that heat so all cells get a portion rather than all of the heat affecting the adjacent cell."

Another design solution is electrically isolating failed cells with fuses when cells are connected in parallel to increase battery capacity. "The design also needs a path that directs the hot gases and vent materials away along a tortuous path which bleeds heat and suppresses flames before they leave the enclosure - while still protecting cell components."

The team also found that new, higher-density cells are adopting slimmer designs, leaving opportunities for ejecta to be released from the cell's sidewall, directly impinging on its neighbor. A rule addressing sidewall ruptures was added, and the team is working to find solutions to strengthen sidewalls without reducing energy output.

RULES OF DESIGN

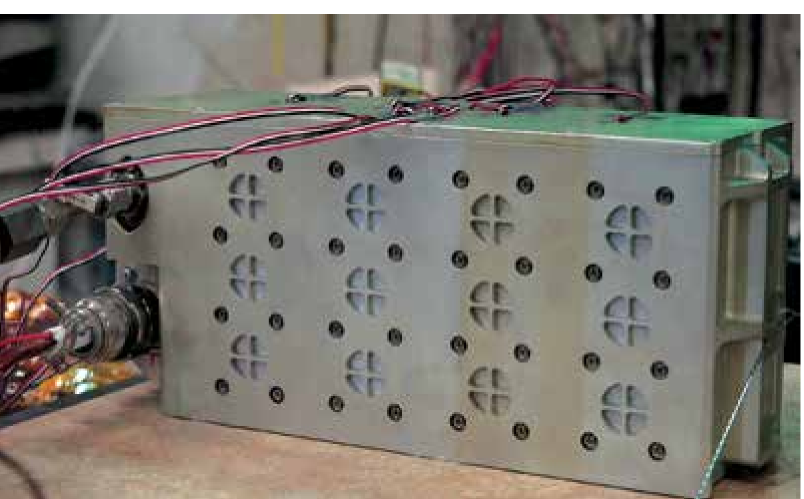
- Reduce the risk of a cell can sidewall rupture
- Provide adequate cell spacing and heat rejection
- Individually fuse parallel cells
- Protect adjacent cells from the hot TR cell ejecta *(solids, liquids, gases)*
- Prevent flames and sparks from exiting the battery enclosure

New Designs at Work

The new rules were applied to designs for three EVA batteries and successfully proven to be nonpropagating. "More effort is needed to address sidewall rupture, testing methods for large cell battery designs, and applicability to higher power batteries," said Dr. Iannello.

Dr. Iannello also said efforts have begun in earnest to share what they've learned with the broader NASA community and industry through conferences, workshops, forums, and meeting with car and battery cell manufacturers. "Our information has been well-received," he said. "People are asking for our data to help them better understand sensitivities and determine which mitigation techniques might help them."

The assessment's final report is one that will be pulled off the shelves and used for years to come," said NESC Director Tim Wilson. "This assessment demonstrated not only the NESC's capabilities, but our ability to do foundational work that affects multiple programs and projects, and industry as well." *For more on Li-Ion batteries, see pages 8 and 51.*



Extravehicular Mobility Unit Portable Life Support System (PLSS) Li-Ion battery redesign/testing

(right) TR induced in a single cell propagates across all cells in a PLSS derived battery pack, resulting in pack failure.

(left) Testing of a flight-like prototype PLSS battery pack that incorporates the rules of design. TR induced in a single cell did not propagate to adjacent cells. While gases escaped through the 12 filtered vents as designed, all sparks, flames and effluents were contained by filters within the pack. The battery continued to provide power.

Richard Russell
NASA Technical Fellow
for Materials

Durability and Damage Tolerance:

A Prerequisite for Deep Space Travel

Just before his retirement in 2017, Dr. Robert Piascik, former NASA Technical Fellow for Materials, presented a white paper to the NESC Review Board illustrating the need for a collaborative effort by the Structures, Materials, and Nondestructive Evaluation (NDE) disciplines to retool the Agency's durability and damage tolerance (D&DT) engineering predictive practices. It was followed by a short presentation by the new NASA Technical Fellow for Materials, Mr. Richard Russell, who outlined his plans for making it happen. This article captures the highlights of that presentation.

Four decades after its launch, NASA's Voyager 1 reached interstellar space, farther than any other human-made object has ever traveled. It was a happy surprise for the mission that was supposed to last 5 years. Today, NASA is designing increasingly complex spacecraft that are incorporating new, advanced materials and raising the bar on performance. It is a necessity for future travel into deep space — where a 50- to 100-year life expectancy for human and science exploration assets will be the expected norm, where spare parts may have to be sacrificed to save weight, and where Earth will be too far away for a repair mission.

"Every asset we send to deep space is going to have extreme value," said Dr. Piascik, former NASA Technical Fellow for Materials. "We can't just replace things. It's too costly. We're not going to have truckloads of traveling spare parts to help repair equipment."

That's why predicting the D&DT of spacecraft and components, especially those that are fracture critical◊, is crucial to long-term mission survival. "We're either going to have extreme reliability in our components so we won't have failures or have separate space platforms for safe haven and repairs," said Dr. Piascik. "The next step, going from low earth orbit to deep space, is not going to be trivial and durability is going to be right in the bull's eye."

After years of working NESC assessments, Dr. Piascik noticed that the Agency's traditional D&DT analysis methods and tools were being pushed well beyond their technical limits in an effort to keep up with the pace of technology. "We are starting to develop and actually fly new designs and new materials, but the design methods are outstripping our ability to predict the durability and damage performance of those components," he said.

> "THE NEXT STEP, GOING FROM LOW EARTH ORBIT TO **DEEP SPACE**, IS NOT GOING TO BE TRIVIAL AND **DURABILITY IS GOING TO BE RIGHT IN THE BULL'S EYE**."

"The wave of the future, and rightfully so, is additive manufacturing (AM)," Dr. Piascik noted as an example. "It's a really unique, powerful way to cheaply and accurately manufacture very complex-configured components, but we don't have the capability to really predict the D&DT behavior. The problem has only intensified as actual testing of components has become cost- and time-prohibitive, and more reliance has shifted to computational D&DT tools.

Dr. Piascik, along with D&DT structures expert and colleague, Dr. Norman Knight, wrote a technical paper (NASA-TM-2017-219621) outlining these concerns. Referencing actual NESC assessments, they cited examples that illustrate the challenges in predicting the D&DT behavior of complex components such as products of AM, multi-functional materials that have multiple grain sizes or interfaces, ceramic composite materials, metallic foams, and more. "We're far from understanding the D&DT of those materials, yet we're pushing forward on their development," Dr. Piascik said.

NASA needs to better position itself for the future by retooling its D&DT engineering predictive practices, he said. Aside from the fundamental need to understand the limits of current engineering methods, Dr. Piascik said the Agency needs to develop new, advanced engineering analysis and testing tools to tackle these emerging complex material systems and manufacturing technologies and the validation testing required to provide a technical understanding that traditional analysis methods alone cannot.

The fix is not an easy one. Dr. Piascik and Dr. Knight offered a long list of recommendations that included providing funding for research; cataloging the current state-of-the-art of computational materials engineering; establishing a multidisciplinary team of NASA Technical Fellows' technical discipline teams (TDT) for Materials, Structures, and NDE; development of computational materials-based testing procedures and engineering analysis methodologies; and many more.

Though Dr. Piascik and Dr. Knight have since retired, their technical paper will serve as a road map for the successor, Mr. Richard Russell, the NESC's new NASA Technical Fellow for Materials, who has already made headway on an action plan. That plan includes establishing TDT working groups, educating the fracture control community via meetings and guidelines development, and development of new tools.

"I've been talking to the TDT groups about working together to collaborate on all the topics that Dr. Piascik talked about," said Mr. Russell. "We really need to identify which standards, specifications, and program requirements need modification to ensure our fracture critical components are properly assessed during the design review process," he said.

"We need to truly understand the limits of our current D&DT methods," concluded Dr. Piascik. "It sounds almost trivial, but we (the Agency) have a problem if we're using our current methods in areas we shouldn't be."

WHAT IS A D&DT TECHNOLOGY SHORTFALL?

Includes the lack of:

- Recognition that some D&DT tools are inappropriate for some advanced designs/materials
- Sufficient testing of new materials and their use to validate analysis methods/models
- Understanding of fundamental assumptions, boundary conditions, and response metrics produced by the computational tools
- Recognition of boundaries between conventional continuum mechanics and non-continuum responses
- Capability to understand and evaluate local material behavior caused by increased reliance of global computational simulation results
- Understanding fracture mechanics similitude concepts and applicability of linear elastic fracture mechanics
- Recognition of importance of local environments on D&DT assessment
- Understanding the role of material length scales and increased dependencies on anisotropy and nonlinearities
- Understanding and cross-communication of existing standard practice guidelines between disciplines

◊ *A fracture critical classification identifies a part, either metallic or composite, whose individual failure is a catastrophic hazard, and which requires damage tolerant analysis or other fracture control assessment to be shown acceptable for flight.*

Photo: Dr. Piascik *(left)* and Mr. Russell shown reviewing a D&DT test method being conducted using a servo hydraulic test machine at a NASA Langley Research Center D&DT laboratory.

Status Update:

Shell Buckling Knockdown Factor Project

The NESC Shell Buckling Knockdown Factor (SBKF) Project was established in March 2007 to develop and experimentally validate new analysis-based shell buckling design factors, i.e., knockdown factors (KDF), for metallic and composite launch vehicle structures. The main goal is to determine if conservatisms applied to Apollo-era KDFs, which account for the unknown variability in cylinder buckling loads, are still warranted with today's advanced technology. The new KDFs will enable weight savings and should help mitigate launch vehicle development and performance risks.

2017 has been a period of transition for the SBKF Project. The development and validation of new KDFs for stiffened metallic cylinders is nearly complete. New KDFs developed from the SBKF Project were used in the design of the Space Launch System (SLS) core stage (CS), resulting in a 5-8% mass savings. Meanwhile, the second phase of the project is making significant progress toward developing new KDFs for composite sandwich cylinders.

New Metallic Cylinder KDFs Nearly Complete

The metallic portion of the SBKF Project is engaged in several close-out activities. The team has completed detailed reviews of analysis and test data from all 10 of its large-scale stiffened metallic cylinder buckling tests and is now in the process of publishing final analysis and test reports. These reports describe the complex response characteristics of the cylinders investigated, the development of high-fidelity buckling simulations, and provide analysis and testing best practices. Two such reports were published in 2017,[1,2] including a report on the buckling analysis of the SLS CS liquid hydrogen (LH2) tank and liquid oxygen (LOX) tank. This report summarizes data needed to satisfy a critical requirement that the design buckling loads based on the new KDFs be conservative, i.e., show positive margin, when compared to the high-fidelity finite-element-based buckling loads for the SLS CS cylinder designs that include the effects of as-measured SLS CS cylinder geometry — also known as geometric imperfections. The high-fidelity results indicate that the SLS CS cryotank cylinders have positive margins over the design buckling loads generated with the new SBKF-derived KDFs. Several more reports are expected to be complete in the spring of 2018, including the revision of NASA Special Publication (SP)-8007, *Buckling of Thin-Walled Circular Cylinders*, published in 1968.[3]

Development of KDFs for Composite Cylinders Continues

The second phase of the SBKF Project is focusing on the development of KDFs for composite cylinders for SLS with plans to test five 8-foot-diameter honeycomb-core sandwich composite cylinders. These cylinders will all have different shell-wall designs (core thickness and material, number and angles of facesheet plies) to interrogate different portions of the SLS design space. The first shell was fabricated by Northrop Grumman and tested successfully last year (2016) in the SBKF 8-foot test facility at MSFC. The project is building the remaining 8-foot-diameter cylinders at the MSFC Composites Technology Center. Toward this objective, the SBKF Project procured an 8-foot-diameter metallic tool on which to build the shells. In addition to these large-scale cylinders, other small-

scale cylinders are being fabricated and tested as part of collaborative work with Delft University of Technology in the Netherlands. These small-scale cylinders will be used to study the effects of scaling on the buckling response of sandwich composite cylinders. Finally, the project is in the process of developing a preliminary set of new KDFs for the cylindrical portion of the SLS Universal Stage Adaptor (USA) in collaboration with the USA Project and Dynetics, the prime contractor on task for the USA development.

The SBKF Team also published NESC Technical Bulletin 16-01, *Buckling Knockdown Factors for Composite Cylinders*, which emphasizes that composite cylinders are outside the scope of SP-8007 and why caution must be taken when using the universal metallic KDF in composite designs. Ultimately, the composite KDFs will be published either in the revised SP-8007 or in a similar document.

Technology Demonstration – Single-Piece Metallic Cylinder Fabrication and Testing

In addition to its main focus areas, the SBKF Project periodically identifies and explores synergistic technology demonstration opportunities. One such opportunity was found in the manufacturing and testing of an 8-foot-diameter single-piece stiffened metallic cylinder. The goal of this activity was two-fold: first, to demonstrate the use of flow-forming technique in the fabrication of a large-scale single piece aluminum cylinder; and second, to demonstrate the improved buckling performance of a cylinder without weld lands. To accomplish this goal, the SBKF Project partnered with the Advanced Materials and Processing Branch at LaRC, MSFC, and ATI Forged Products to design and fabricate an aluminum 8-foot-diameter orthogrid-stiffened single-piece metallic cylinder, i.e., with no weld lands. The cylinder acreage design is essentially the same as one of the previously tested welded metallic cylinders, so that a direct comparison between welded and single-piece cylinders could be made. Testing was conducted in the SBKF buckling test facility at MSFC in April 2017. The test results indicated a 28% increase in load carrying capability by removing the weld lands from the cylinder.

References:

1. Hilburger, M.W.; Satyanarayana, A.; Schultz, M.R.; and Oremont, L: *Buckling Analysis of the Space Launch System (SLS) Core Stage Ringless Cryotanks – Updated Buckling Load Predictions Based on As-Built SLS Cryotank Barrel Geometry*, NASA/TM-2017-219373, February 2017 (ITAR)

2. Hilburger, M.W.; Waters, W.A.; and Haynie, W.T.: *Buckling Test Results and Preliminary Test and Analysis Correlation from the 8-Foot-Diameter Orthogrid-Stiffened Cylinder Test Article TA02*, NASA/TM-2017-219587, March 2017.

3. Anonymous: *Buckling of Thin-Walled Circular Cylinders*. NASA Space Vehicle Design Criteria, NASA SP-8007, 1965 (revised 1968).

Photos (*clockwise from top left):*
An automated fiber placement robot in the MSFC Composites Technology Center builds an 8-foot-diameter composite cylinder under control of materials engineer, Ms. Casey Wolfe.

An 8-foot composite cylinder being prepared for testing.

Fabrication of an 8-foot-diameter single-piece stiffened metallic cylinder (without weld lands). This test article showed increased buckling performance over welded cylinders.

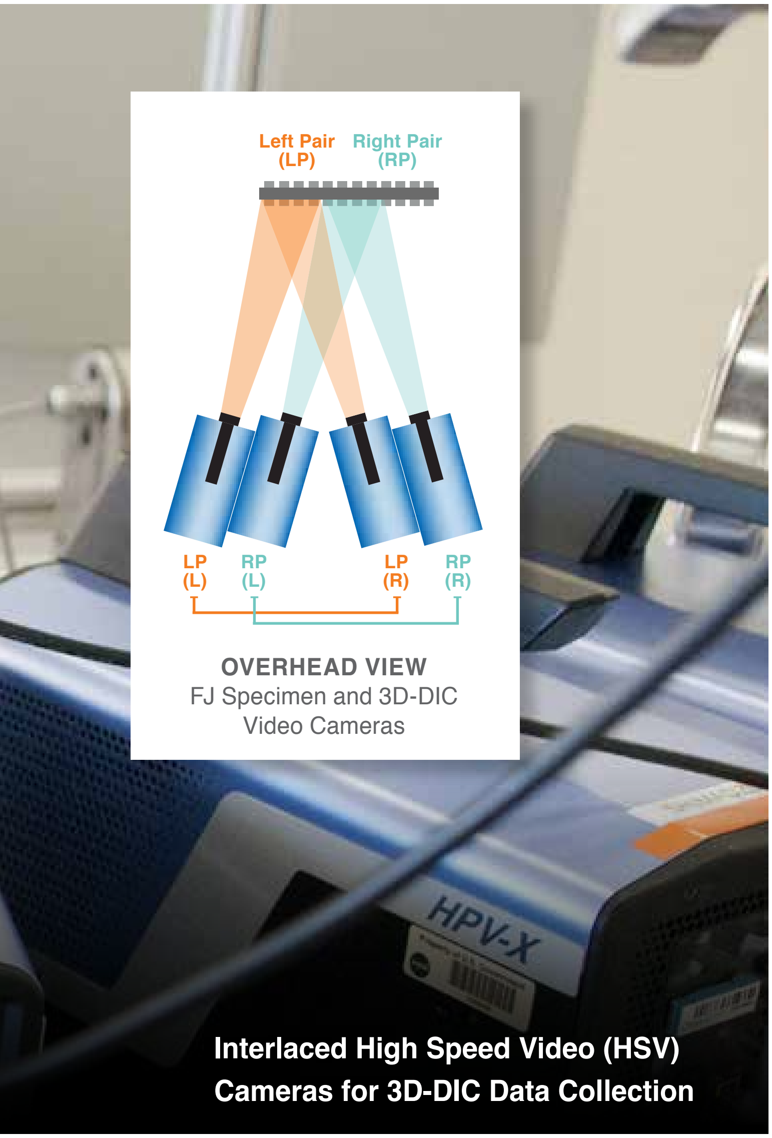
Section of a Space Shuttle 27-foot-diameter external tank was used in development of metallic cylinder KDFs.

High Speed Structural Measurement Technique Development and Validation

Frangible joints (FJ) are pyrotechnic devices used as spacecraft separation systems between rocket stages or as part of payload fairings. The NESC examined design sensitivities, margins, and estimated reliability for several FJ types. High-speed structural measurements were necessary to transition from a binary form of testing, i.e., post-detonation observation of FJ separation (pass/fail) to a continuous measurement of performance that enables margin quantification and reliability estimation. To that end, the NESC team achieved measurements using Photon Doppler Velocimetry (PDV) and high-speed video (HSV) cameras to perform three-dimensional digital image correlation (DIC) to better characterize FJ operation.

Digital Image Correlation Measurement Validation

The NESC team was faced with the challenge of making accurate structural response measurements for an event lasting just microseconds. DIC was the leading candidate to provide surface strains, three-axis displacements, and three-axis velocities. DIC was understood for quasi-static and high-speed applications, but needed to be validated for ultra-high-speed conditions. The validation was performed using three techniques with disparate physics: foil strain gages, fiber optic (FO) strain sensors, and PDV. The surface mounted sensor comparisons (foil and FO strain gages) were limited due to the sensors departing the surface shortly after local detonation.



Interlaced High Speed Video (HSV) Cameras for 3D-DIC Data Collection

However, the comparison with PDV was against the entire duration of each DIC video record, and across all 143 tests in the 2.5-year test program.

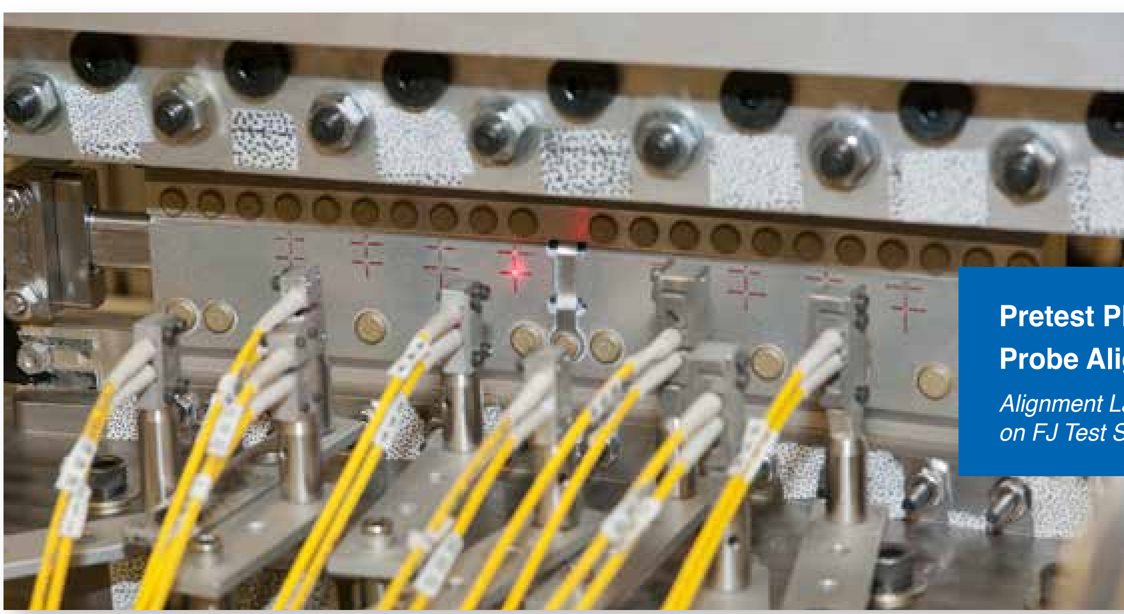
The final result was the demonstration of a validated DIC measurement system providing the aforementioned nine parameters across an approximately 3-inch x 6-inch area at 1 million frames per second *(see referenced area at left)*. Data from DIC enabled the team to discover, quantify, and explain boundary effects, locations of minimum margin, and generate qualification and acceptance testing requirements.

Photon Doppler Velocimetry Measurement Validation

The best data to characterize the impulsive loading was high-speed velocity data at points on the surface of the FJ, and the best data to characterize the fracture events was high-speed velocity data at a different set of points on the surface of the FJ. PDV data collected at 10 mega samples per second met the requirements, and was validated three different ways. The first method involved measuring a point on a flywheel at a well-known rotation rate. The second method was stated above, comparing against DIC data. The third method utilized sub-pixel resolution velocity data derived from collocated HSV. All three methods compared well.

The final result was the demonstration of a validated PDV system providing ultra-high-speed velocity data. This enabled the team to accurately measure the impulsive loading and structural response, resulting in a continuous variable description of FJ performance, successfully determining margin, and estimating reliability.

For more information, contact:
Christopher Kostyk
Armstrong Flight Research Center
chris.b.kostyk@nasa.gov



Pretest PDV Probe Alignment

Alignment Laser Spots Shown on FJ Test Specimen

Deterministic System Design of Experiments for Frangible Joint Design Reliability

A deterministic system Design of Experiments (dsDOE) method was developed for frangible joints (FJ) to enable rapid estimation of their design reliability. Design reliability means there is an acceptable degree of certainty that the FJ will fracture/actuate when commanded. FJs are typically used in critical applications to separate stages of a launch vehicle or payload shrouds. As part of an NESC-sponsored investigation into FJ reliability, this new method combined a finite element model (FEM) morphing technique with statistical modeling and analysis to develop surrogate models of FJs. These surrogate models were then employed to analyze millions of Monte Carlo-generated configurations and predict design reliability. An overview of the approach is illustrated in *Figure 1*.

Morphing of FJ FEM models was employed to rapidly generate hundreds of FEM configurations for subsequent LS-DYNA (a commercially available non-linear FEM code) analysis. The variations in FJ design parameters were generated via DOE methods, and FEM pre-processing capabilities were used to alter a "base" FEM to the desired configurations while minimizing mesh distortion and maintaining element quality. The method also retains all nodes, elements, and boundary conditions in the original "base" model and does not require remeshing, thus increasing analysis throughput. Automating the process enabled hundreds of varied FEM configurations to be generated in about an hour. *Figure 2* shows an example of morphing on a FJ ligament.

After generating LS-DYNA response data on the morphed models, statistical models were fit to the resulting metrics to develop polynomial equations that predict the LS-DYNA response over multivariate space, aka surrogate models. These surrogate models were then coupled with statistical distributions of the input variables to run a 10-million case Monte-Carlo analysis and determine the overall distribution of the model's primary output response metric, designated as AvgVelW *(Figure 3)*, which represents an average velocity response. The fracture/no fracture result of the LS-DYNA analysis was further used to develop logistic fits to this binary response for fractures occurring within 30 μs, 40 μs, and within an unlimited amount of time from commanding. This logistic fit provided a probability of fracture for varying surrogate model output responses. The design reliability was then calculated by dividing total number of expected fractures by 10 million. *Figure 3* illustrates the resulting logistic and output distributions used to calculate design reliability.

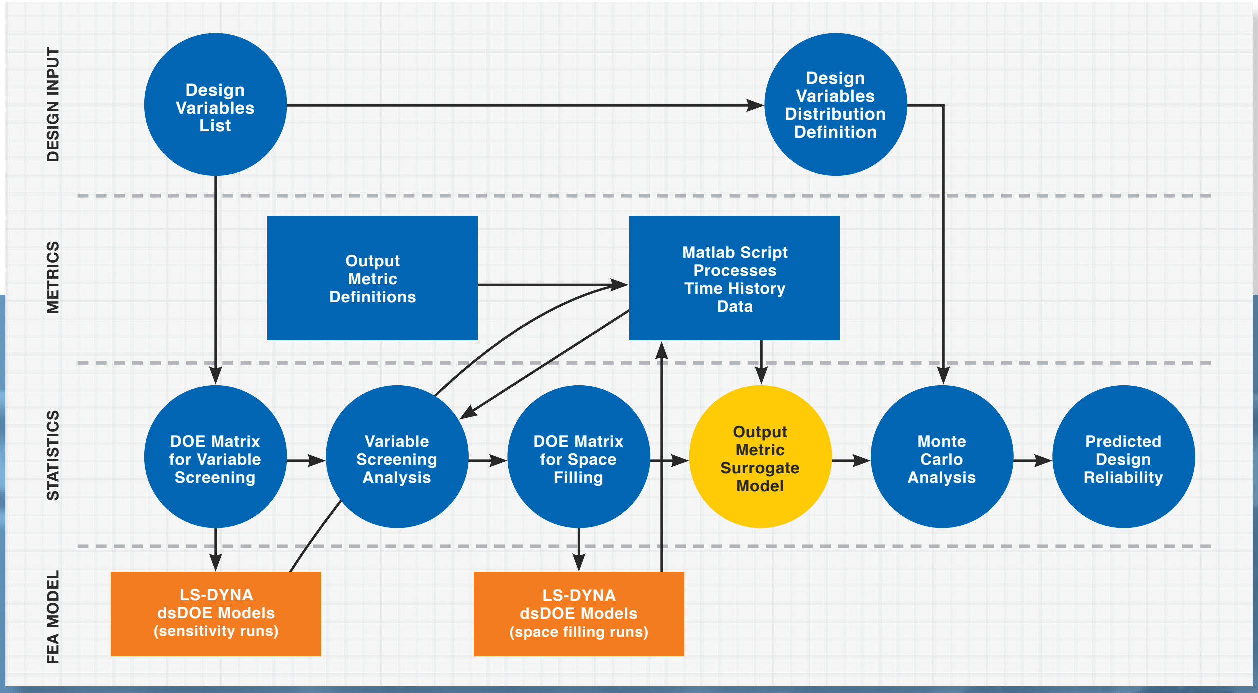
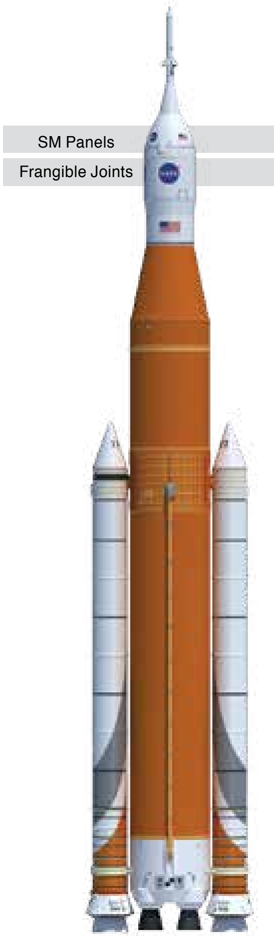
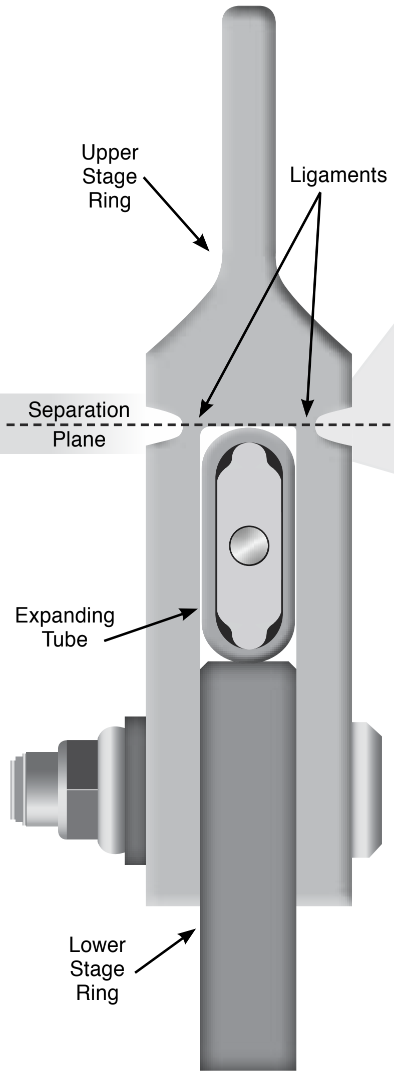


Figure 1: Deterministic system Design of Experiments (dsDOE) process.





Frangible Joint Cross Section
(approximate)
Used to jettison service module (SM) panels.

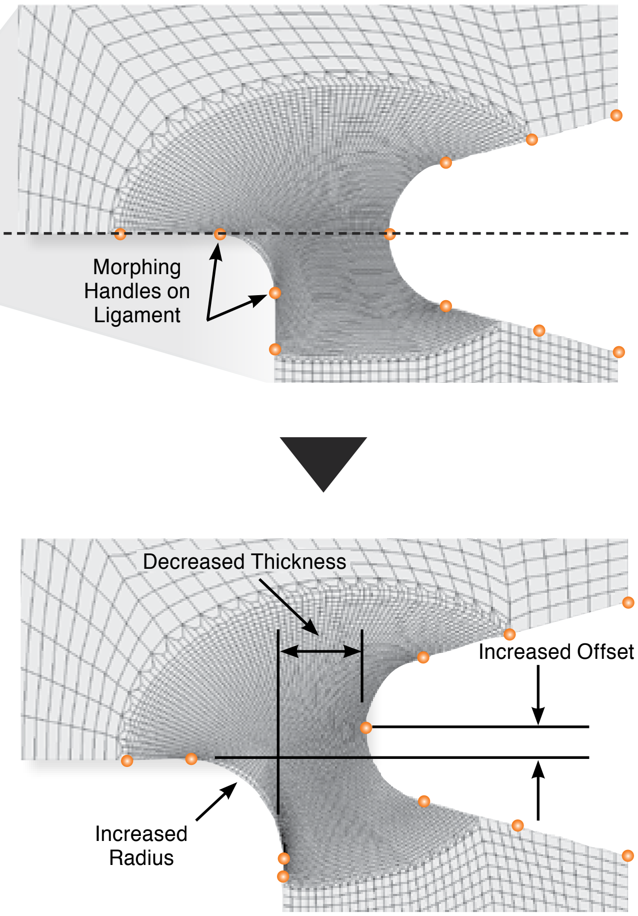


Figure 2: Morphing from "base" FEM to alter ligament geometry.

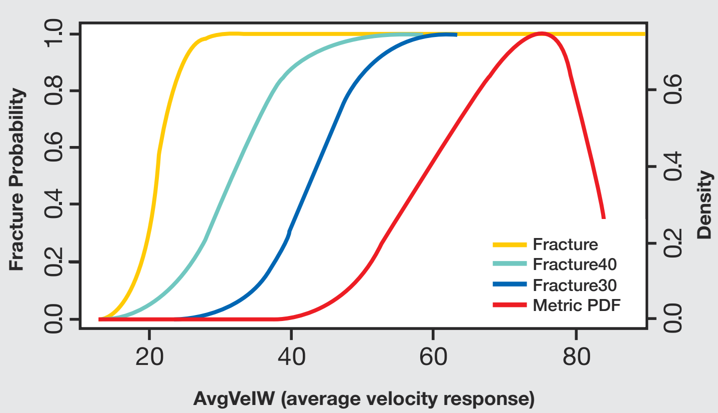


Figure 3: Surrogate model output metric probability distribution function and probability of fracture curves.

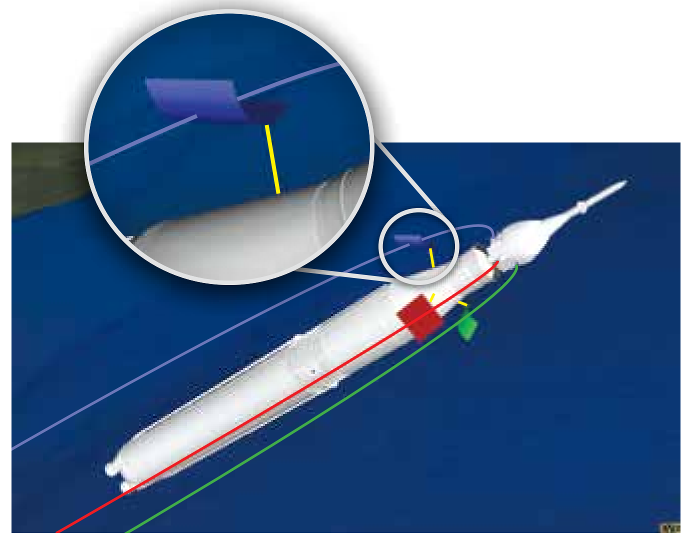
For more information, contact:
Scott West
Johnson Space Center
timothy.s.west@nasa.gov

Spacecraft Proximity Analysis Using the Exploration Visualization Environment

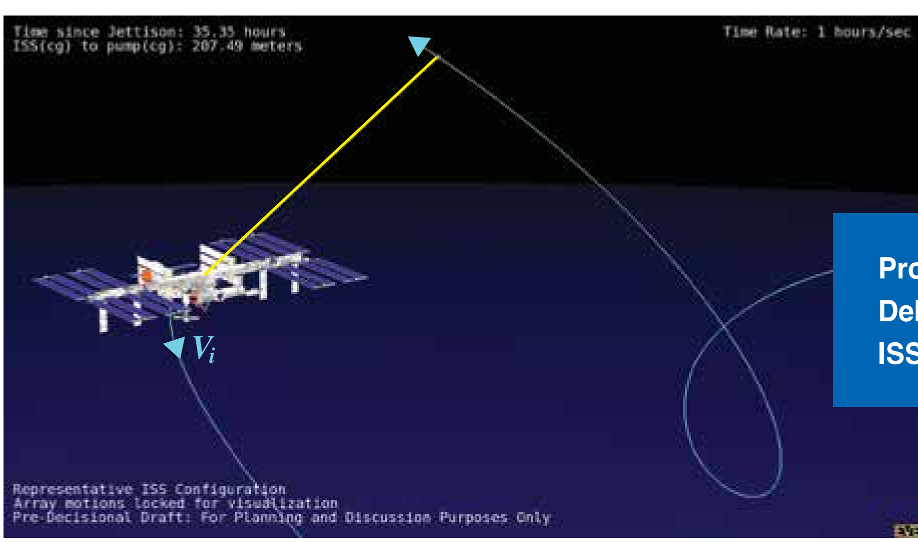
A graphical proximity analysis tool has been developed to aid in the study of spacecraft separation events. The NESC has been tasked with the requirement to analyze the separation events of numerous spacecraft operational scenarios, including the launch sequence of the Space Launch System (SLS), the separation of the launch abort system for the Commercial Crew Program, and the jettison of debris from the International Space Station (ISS). In each case, the complex relative motions between all spacecraft components are analyzed. The spacecraft and component trajectories are first simulated in the Program to Optimize Simulated Trajectories II (POST2). POST2 provides a generalized framework for simulating six degree-of-freedom masses for powered or unpowered vehicles near arbitrary rotating oblate planets. Obtaining and understanding the proximities between vehicle parts down to the closest point of approach for clearance analysis requirements, however, requires accurate geometric representations of the vehicles driven by the point mass dynamics. To that end, the Exploration Visualization Environment (EVE) tool, has been introduced. EVE has been used extensively to support space mission analysis requirements for programs and projects such as ISS assembly and operations, ISS payload operations, Mars Exploration Rovers, Ares 1X, Lunar Habitats and Landers, the Asteroid Redirect Missions, and human exploration of Mars.

EVE is a simulation, visualization, and analysis system designed to integrate time-dependent engineering data with detailed graphical models within a full-scale virtual environment. A useful EVE capability is that of proximity analysis. By taking the detailed engineering data provided by POST2 and integrating it with very detailed geometric models, EVE can analyze the system to determine the closest point of approach between objects. An extension was created for POST2 to enable a more formalized transfer of data between POST2 and EVE. Using EVE's interactive virtual environment, the user obtains almost immediate feedback for a given POST2 analysis run by viewing the simulation in real time, visualizing proximity results in context of the mission scenario and events. The user also has the option to analyze thousands of POST2 simulation runs, such as those performed through Monte Carlo analysis, using an offline batch analysis mode. The results of the analyses are stored in report files, providing proximity distance data as a function of time for all analysis runs. Specific runs can be brought back into EVE and visualized as required. Using the built in media capture system, the user may export images and animations showing points of closest approach. The flexibility of EVE and POST2 are continually improved through regular maintenance and updates. In addition, EVE is adaptable to any trajectory program. EVE is available to all NASA programs and projects.

More information on EVE and POST2 can be found at eve.larc.nasa.gov and post2.larc.nasa.gov.



The yellow lines show the closest point of approach between each panel and the SLS core body, while the red, green, and blue lines show the path of each panel.



Proximity of Jettisoned Debris Relative to the ISS after 35 Hours

The cyan line shows the track of the debris and the yellow line connects the closest point on each object.

Advanced Modeling of Rocket Explosion Events

A new capability for modeling propellant explosion events has been developed. Testing and launching of chemical rocket propulsion systems inherently involve the risk of large energy explosions. The ability to predict these blast environments is critical to the safety of the facility, test article, and possibly flight crew members. NASA's current standard is to utilize conservative analytical engineering methods to estimate the explosion energy and subsequent blast propagation for maximum credible events. These methods typically first assume a detonation event occurs and then equates the propellant vapor cloud explosion to a high-density explosive. While this methodology is adequate for providing blast overpressures at sufficient distances from the detonation source, it lacks the fidelity to predict the near-field explosion dynamics. In addition, it is incapable of directly assessing the probability or severity of the explosion event.

The current technology was accomplished by leveraging work done as part of a recent NESC investigation into developing validated tools for blast wave propagation modeling. While significant accomplishments were made during that investigation, one of the key recommendations was to determine a valid and engineering-level approach for predicting vapor cloud explosion sources. This was the key motivation for an FY15 Center Innovation Fund project at Stennis Space Center (SSC) that focused on robust and accurate computational fluid dynamics (CFD) modeling for hydrogen combustion and explosion dynamics. The new technology was implemented in the Loci/CHEM CFD tool suite, which originally was developed by Mississippi State University. The results of this effort in predicting the occurrence and effects of hydrogen propellant deflagration and detonations were documented recently in the NASA Technical Publication, NASA/TP-2016-219220.

Application of the new explosion modeling technology was conducted recently to address concerns regarding potential hydrogen explosions on the SSC B-1/B-2 Test Stands. Specifically, it was necessary to quantify the impact of possible explosion scenarios on the SLS Core Stage. A team from SSC, MSFC and Bangham Engineering, Inc., exploded balloons filled with hydrogen-oxygen mixtures. A snapshot of one of the explosion events is provided in *Figure 1*. Blast probes were positioned throughout the test facility to obtain the overpressure environments generated. CFD analyses of the hydrogen-oxygen balloon explosions were also conducted with the newly developed modeling tool. A visualization of the shock and compression waves predicted for the explosion is shown in *Figure 2*. These types of results provided a greater understanding of the flame-acoustic coupling that was occurring in the combustion zone. In addition, the CFD modeling approach was proven to predict both the near- and far-field overpressures with excellent agreement to the empirical data obtained. Current efforts are now focused on expanding the modeling capability to include hydrocarbon propellants.

For more information, contact Danny Allgood, Stennis Space Center, daniel.c.allgood@nasa.gov.

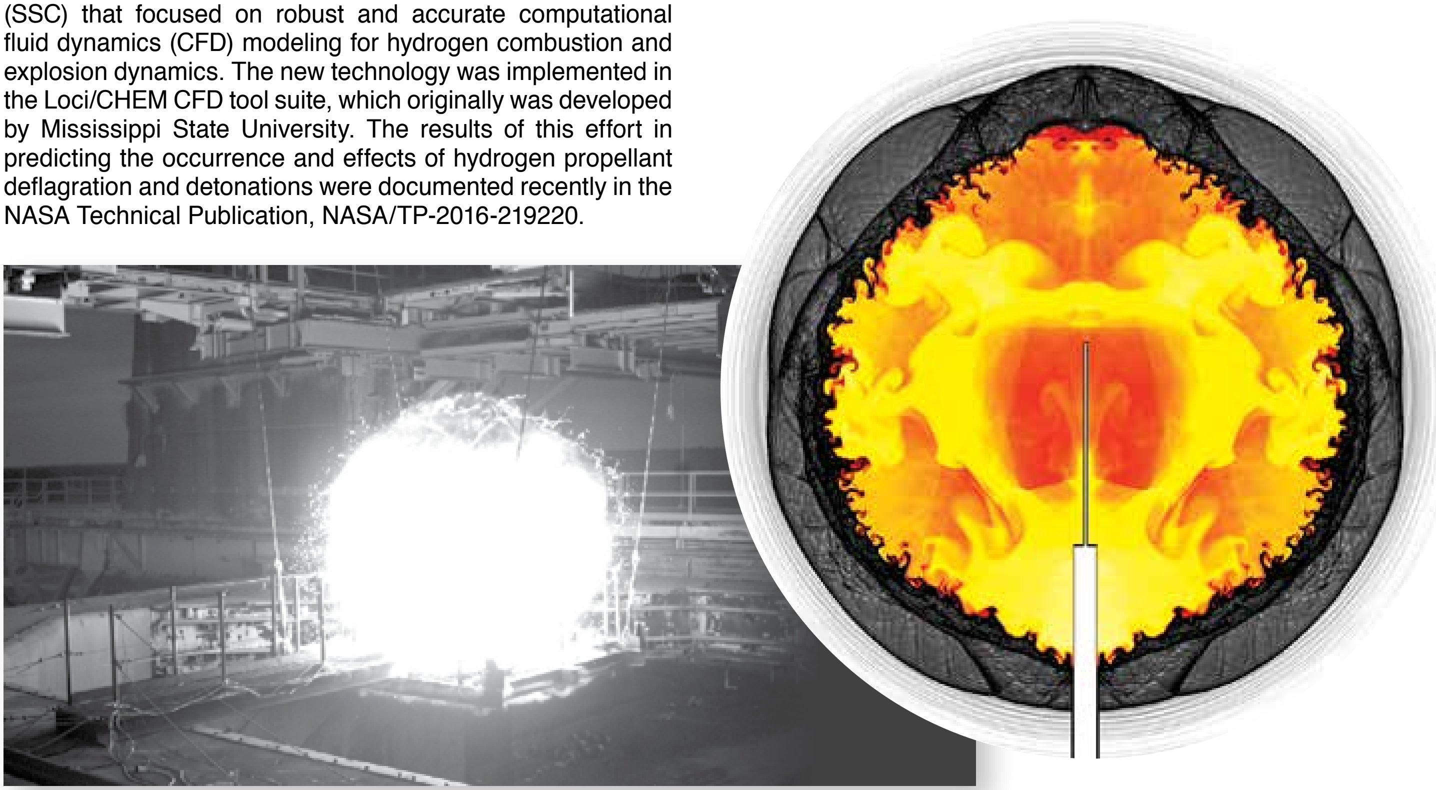


Photo: Explosion of a hydrogen-oxygen filled balloon on the B-1 Test Stand at NASA Stennis Space Center. The Hydrogen Unconfined Test Apparatus (HUCTA) device used for generating the near spherical explosion was provided by Bangham Engineering, Inc. **Illustration:** CFD Predictions of the HUCTA device. Grey scale contours are a numerical Schlieren image depicting shock and compression waves ahead of the flame front. The combustion zone is indicated by the superimposed color contours of gas temperature.

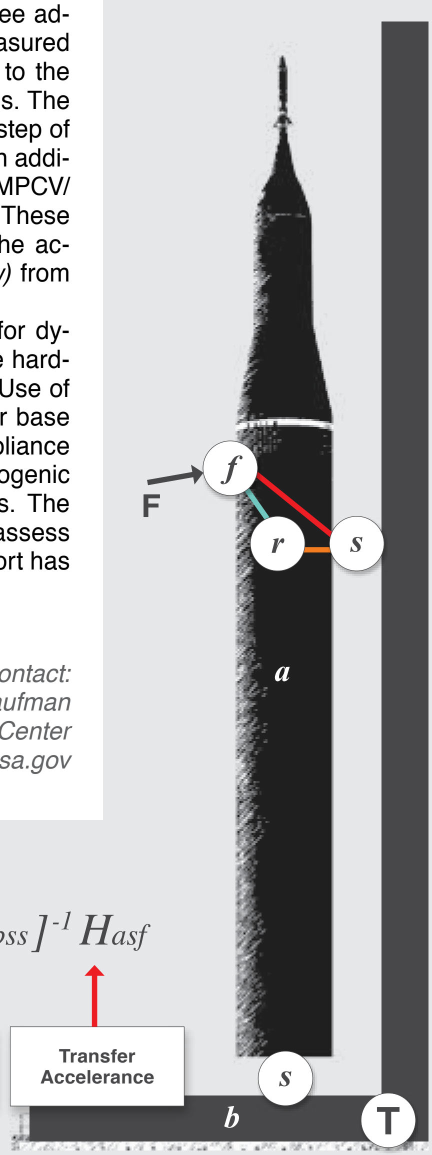
Accelerance Decoupling for Modal Test

A new methodology for modal tests has been developed called Accelerance Decoupling (AD), which overcomes the problem that free-free modal data could not be directly obtained from the integrated vehicle while on launch platform. This methodology is being applied to acquire the free-free modal data needed by the Space Launch System (SLS) vehicle for loads and flight controls, which cannot be directly obtained from the integrated SLS/mobile launcher (ML) test in the Vehicle Assembly Building. The ML represents an elastic boundary condition for the combined Multi-Purpose Crew Vehicle (MPCV)/SLS and it is non-traditional (neither fixed nor free-free) and very challenging for a modal test.

AD solves the problem by reversing the coupling process used in the receptance coupling method. In addition, AD provides a solution that meets three additional desirable conditions: it uses only measured data, does not require measurements internal to the ML, and it solves directly for the free-free modes. The methodology does not require an intermediate step of model correlation. AD does, however, require an additional set of measurements be made from the MPCV/SLS/ML and ML modal tests in this example. These measurements are required in order to form the accelerance matrices *(see matrix equation below)* from which the decoupling process is implemented.

AD is also expected to be of high value for dynamic interaction tests of spacecraft and space hardware when attached to their integration stand. Use of the methodology avoids needing to suspend or base isolate the hardware to verify on-orbit jitter compliance caused by disturbance sources such as cryogenic coolers, step motors, and sensor mechanisms. The methodology is currently being evaluated to assess noise tolerance. A NASA New Technology Report has been filed. e-NTR#: 1499964335.

For more information, contact:
Daniel Kaufman
Goddard Space Flight Center
daniel.s.kaufman@nasa.gov



$$H_{arf} = H_{crf} + H_{ars} \left[H_{ass} + H_{bss} \right]^{-1} H_{asf}$$

Transfer Accelerances | Driving Point Accelerances | Transfer Accelerance

ACCELERANCE DECOUPLING METHODOLOGY

Matrix Subscript Key:

a - SLS
b - Mobile Launcher + Tower
c - SLS + Mobile Launcher + Tower

Fast Coupled Loads Analysis Method:

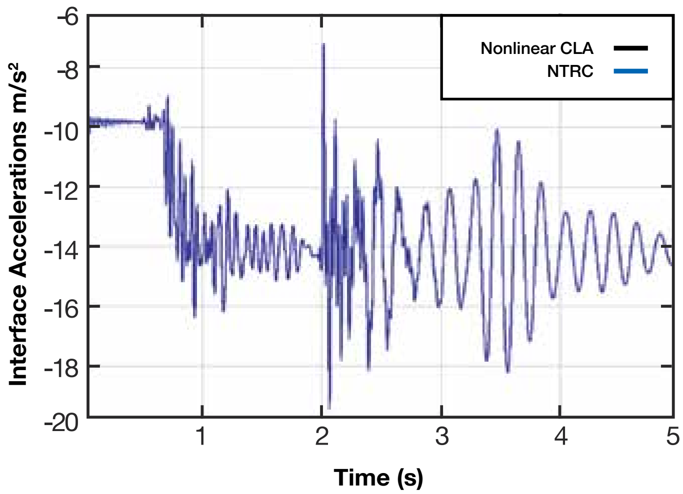
Norton-Thevenin Receptance Coupling

A new method called Norton-Thevenin Receptance Coupling (NTRC) has been developed to perform coupled loads analysis (CLA). NTRC attempts to reduce the dependency of the payload organization on high CLA costs, long analysis schedules, lack of standard capabilities to evaluate multiple payload configurations, and unavailability of launch loads from the launch vehicle (LV) provider when needed.

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 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, perform trade studies, and perform parametric loads analysis 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 launch vehicle to payload/s 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 response 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. A NASA New Technology Report has been filed. e-NTR#: 1450108519. *For more information, contact Daniel Kaufman, Goddard Space Flight Center, daniel.s.kaufman@nasa.gov.*



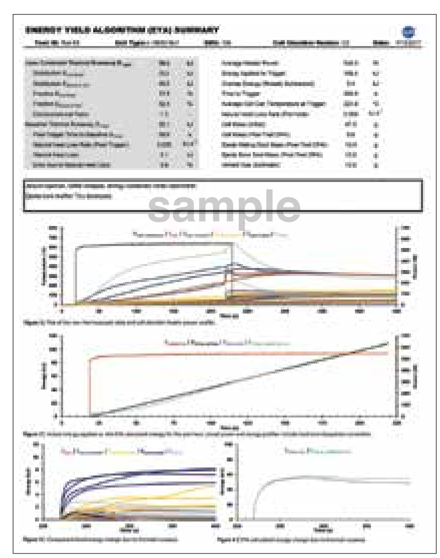
Interface accelerations in LV thrust direction capturing all relevant characteristics of Pad Separation CLA.

Calorimetry of Lithium-ion Cells During Thermal Runaway

Lithium-ion (Li-Ion) cells are widely used in consumer products. Recent well-publicized events involving Li-Ion batteries in devices such as laptop computers, electric cars, commercial aircraft and even toys have drawn attention to the phenomenon of thermal runaway – where stored energy within the cell is rapidly released as heat along with vented effluents. With increased use of Li-Ion cells in space applications such as extravehicular activity hardware, care must be taken to ensure the battery design does not promote propagation of thermal runaway to adjacent cells.

Thermal runaway can be studied through calorimetry - a precise measurement of heat liberated during the thermal runaway process. Existing calorimetric methods such as Accelerating Rate Calorimetry (ARC) provide data on the total energy yield from a cell during thermal runaway. But ARC cannot separate the fraction of energy conducting through the cell casing from that venting from the cell. Understanding how the released energy is apportioned informs the design process, improves the ability to model heat transfer in the battery and allows for more effective thermal runaway mitigations in the battery design.

A new calorimeter for the popular 18650-sized Li-Ion cell has been developed under an NESC assessment and is designed to measure the total energy yield as well as the fractions conducted and vented. An instrumented cell is placed into the cell chamber and heated until thermal runaway is triggered. Separate heat transfer paths measure the energy yield from the cell as its energy is conducted through the calorimeter. Effluents can be collected for further analysis. *For more information, contact: Steven Rickman, Johnson Space Center, steven.l.rickman@nasa.gov.*



The calorimeter's energy yield algorithm software tallies the energy release by analyzing temperature changes in the calorimeter as a result of the thermal runaway.

Left to right: **FRONT ROW** Dwayne Morgan (WFF); Neil Dennehy (NESC); Michelle Rudd (MSFC); Marta Shelton (WFF); Mark Balas (Univ. of Tenn.); Peter Berg (Aerodyne Industries); Dawn Schaible (NASA Deputy Chief Engineer/presenter); Timmy Wilson (NESC Director/presenter); **SECOND ROW** Michael Kirsch (NESC Deputy Director/presenter); Yuan Chen (LaRC); Jonathan Tylka (WSTF); Raymond Ladbury (GSFC); Simone Hurley (LaRC); Jessica Knizhnik (GSFC); Omar Torres (LaRC); **THIRD ROW** Alan Davis (Jacobs Engineering); Tannen VanZwieten (NESC); Christopher Matty (JSC); Christopher Kostyk (AFRC); Karen Weiland (GRC); Marc Sarrel (JPL); Darren McKnight (Integrity Applications, Inc.); Daniel Hicks (MSFC); *Not pictured:* Joe Blondin (independent consultant)

NESC Director's Award

Honors individuals who take personal accountability and ownership in initiating clear and open communication on diverse and controversial issues. A key component of this award is based on the process of challenging prevailing engineering paradigms.

Christopher B. Kostyk In recognition of persistence and extraordinary attention to detail in personally assessing and correcting the redactions to the voluminous commercial crew program frangible joint final technical report, thus averting the release of commercial crew partner proprietary data

NESC Leadership Award

Honors individuals who have had a pronounced effect upon the technical activities of the NESC.

Bruce A. Davis In recognition of outstanding leadership in coordinating the NASA Engineering and Safety Center's hypervelocity impact testing for the Micrometeoroid and Orbital Debris Pressure Vessel Failure Criteria Assessment

Dwayne R. Morgan In recognition of outstanding engineering leadership in support to the NASA Engineering and Safety Center's Commercial Crew Program Avionics Architecture Review Assessment

Michelle T. Rudd In recognition of outstanding execution of the NASA Engineering and Safety Center's Shell Buckling Knockdown Factor Project 8-ft diameter seamless metallic barrel buckling test

Omar Torres In recognition of outstanding technical leadership as the Guidance, Navigation, and Control co-lead of the NASA Engineering and Safety Center's Commercial Crew Program Avionics Architecture Review Assessment

Karen J. Weiland In recognition of exceptional leadership in the planning and implementation of the NASA Model-Based Systems Engineering pathfinder

NESC Engineering Excellence Award

Honors individual accomplishments of NESC job-related tasks of such magnitude and merit as to deserve special recognition.

Mark Balas In recognition of engineering excellence to the NASA Engineering and Safety Center's stability assessment of the Space Launch System Flight Control System

Joe B. Blondin In recognition of engineering excellence to the Hubble Space Telescope Gyroscope Anomaly and Reliability Investigation in support of the NASA Engineering and Safety Center's elevated motor current investigation

Yuan Chen In recognition of engineering excellence to the NASA Engineering and Safety Center in establishing approaches and guidelines regarding the use of commercial-off-the-shelf Electrical, Electronic, and Electromagnetic parts for the Commercial Crew Program and other NASA flight programs

Raymond L. Ladbury In recognition of engineering excellence

NESC Honor Awards

NESC Honor Awards are given each year to NASA Center employees, industry representatives, and other stakeholders for their efforts and achievements in the areas of engineering, leadership, teamwork, and communication.

These honorary awards formally identify individuals and groups who have made outstanding contributions to NESC's mission and who demonstrate the following characteristics:

Engineering and Technical Excellence and Fostering an Open Environment

to the NASA Engineering and Safety Center's Avionics Electrical, Electronic, and Electromagnetic parts radiation guideline activities for the Commercial Crew Program and other NASA spaceflight programs

Christopher M. Matty In recognition of engineering excellence for analysis of the F/A-18 Environmental Control System in support of the NASA Engineering and Safety Center's Physiological Episode Assessment Team

Marc A. Sarrel In recognition of engineering excellence in support of the NASA Engineering and Safety Center's Exploration Systems Development and Commercial Crew Program Verification and Validation Assessments

Marta B. Shelton In recognition of engineering excellence for data and analysis support of the NASA Engineering and Safety Center's F/A-18 Physiological Episode Assessment for the United States Navy

Jonathan M. Tylka In recognition of engineering excellence in support of the NASA Engineering and Safety Center's Additively Manufactured Metals in Oxygen Systems task

NESC Administrative Excellence Award

Honors individual accomplishments or contributions that contributed substantially to support NESC's mission.

Simone E. Hurley In recognition of outstanding human resource support to the NASA Engineering and Safety Center

NESC Group Achievement Award

Honors a group of employees comprised of government and non-government personnel for outstanding accomplishment through the coordination of individual efforts that have contributed substantially to the accomplishment of the NESC's mission.

Commercial Crew Program Avionics Architecture Review Team In recognition of outstanding engineering excellence and leadership to the NASA Engineering and Safety Center's Commercial Crew Program Avionics Architecture Review Assessment

Cross Program Verification and Validation Integration and Mapping Assessment Team In recognition of outstanding technical achievement in support of the NASA Engineering and Safety Center's Exploration Systems Development Cross Program Verification and Validation Integration and Mapping Assessment

Evaluation of Micrometeoroid and Orbital Debris Risk Predictions with Available On-Orbit Assets Team
In recognition of the effort to compare spacecraft risk to recorded failures in order to evaluate NASA's micrometeoroid and orbital debris risk assessment process

Model Based Systems Engineering Pathfinder Team
In recognition of exceptional innovation and passion in the pursuit of modernizing NASA's Systems Engineering capacity via model based systems engineering

OFFICE OF THE DIRECTOR

Timmy R. Wilson
Director

Michael T. Kirsch
Deputy Director

Michael P. Blythe
Deputy Director for Safety

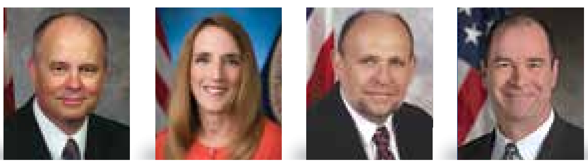
Jill L. Prince
Manager, NESC Integration Office

Dr. Daniel Winterhalter
Chief Scientist

Patrick A. Martin
NASA HQ Senior S&MA Integration Manager

Vacant
Chief Astronaut

NESC PRINCIPAL ENGINEERS



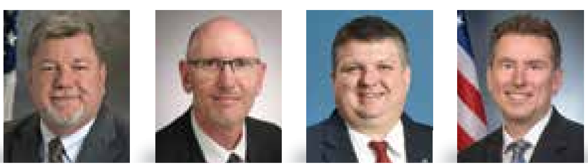
Clinton H. Cragg

Dr. Nancy J. Currie-Gregg

Dr. Michael G. Gilbert

Michael D. Squire

NESC CHIEF ENGINEERS



Steven J. Gentz
MSFC

Kenneth R. Hamm, Jr.
ARC

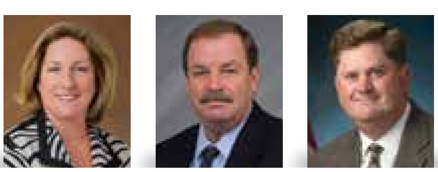
George L. Jackson
GSFC

Robert S. Jankovsky
GRC

Stephen A. Minute
KSC

Dr. W. Lance Richards
AFRC

Paul W. Roberts
LaRC



Kimberly A. Simpson
JPL

Michael D. Smiles
SSC

T. Scott West
JSC

NASA TECHNICAL FELLOWS

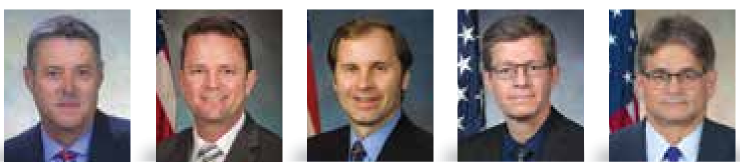
Michael L. Aguilar
Software

Dr. Thomas M. Brown
Propulsion

Cornelius J. Dennehy
Guidance, Navigation, and Control

Dr. Michael J. Dube
Mechanical Systems

Oscar Gonzalez
Avionics



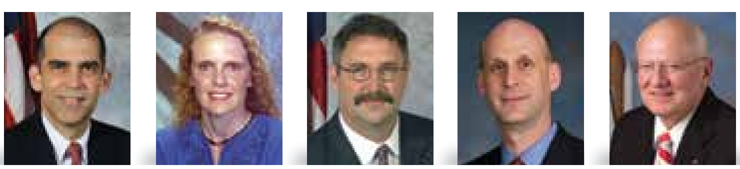
Jon B. Holladay
Systems Engineering

Dr. Christopher J. Iannello
Electrical Power

Dr. Curtis E. Larsen
Loads and Dynamics

Michael L. Meyer
Cryogenics

Dr. Joseph I. Minow
Space Environments



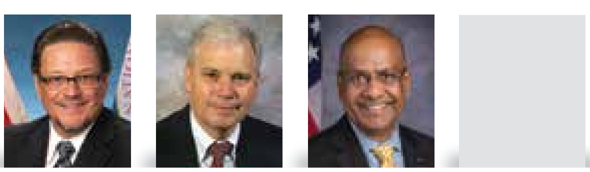
Daniel G. Murri
Flight Mechanics

Dr. Cynthia H. Null
Human Factors

Dr. William H. Prosser
Nondestructive Evaluation

Steven L. Rickman
Passive Thermal

Henry A. Rotter
Environmental Control/Life Support



Richard W. Russell
Materials

Dr. David M. Schuster
Aerosciences

Dr. Upendra N. Singh
Sensors/ Instrumentation

Vacant
Structures

NESC Leadership

See nesc.nasa.gov for full bios

FRANK H. BAUER
NESC Discipline Expert for Guidance Navigation and Control (2003-04)

J. LARRY CRAWFORD
NESC Deputy Director for Safety (2003-04)

DR. CHARLES J. CAMARDA
NESC Deputy Director for Advanced Projects (2006-09)

KENNETH D. CAMERON
NESC Deputy Director for Safety (2005-08)

STEVEN F. CASH
NESC Chief Engineer at Marshall Space Flight Center (2005)

DERRICK J. CHESTON
NESC Chief Engineer at Glenn Research Center (2003-07)

MITCHELL L. DAVIS
NASA Technical Fellow for Avionics (2007-09)

DENNIS B. DILLMAN
NESC Chief Engineer at NASA Headquarters (2005-08)

FREDDIE DOUGLAS, III
NESC Chief Engineer at Stennis Space Center (2007-08)

PATRICIA L. DUNNINGTON
Manager, Management and Technical Support Office (2006-08)

DAWN C. EMERSON
NESC Chief Engineer at Glenn Research Center (2011-14)

WALTER C. ENGELUND
NESC Chief Engineer at Langley Research Center (2009-13)

PATRICK G. FORRESTER
NESC Chief Astronaut (2009-16)

WAYNE R. FRAZIER
Senior SMA Integration Manager (2005-12)

DR. MICHAEL S. FREEMAN
NESC Chief Engineer at Ames Research Center (2003-04)

T. RANDY GALLOWAY
NESC Chief Engineer at Stennis Space Center (2003-04)

ROBERTO GARCIA
NASA Technical Fellow for Propulsion (2007-13)

DR. EDWARD R. GENERAZIO
NESC Discipline Expert for Nondestructive Evaluation (2003-05)

DR. RICHARD J. GILBRECH
NESC Deputy Director (2003-05)

MICHAEL HAGOPIAN
NESC Chief Engineer at Goddard Space Flight Center (2003-07)

DAVID A. HAMILTON
NESC Chief Engineer at Johnson Space Center (2003-07)

DR. CHARLES E. HARRIS
NESC Principal Engineer (2003-06)

DR. STEVEN A. HAWLEY
NESC Chief Astronaut (2003-04)

MARC S. HOLLANDER
Manager, Management and Technical Support Office (2005-06)

GEORGE D. HOPSON
NASA Technical Fellow for Propulsion (2003-07)

KEITH L. HUDKINS
NASA Headquarters Office of the Chief Engineer Representative (2003-07)

DANNY D. JOHNSTON
NESC Chief Engineer at Marshall Space Flight Center (2003-04)

MICHAEL W. KEHOE
NESC Chief Engineer at Dryden Flight Research Center (2003-05)

R. LLOYD KEITH
NESC Chief Engineer at Jet Propulsion Laboratory (2007-16)

DENNEY J. KEYS
NASA Technical Fellow for Electrical Power (2009-12)

DR. DEAN A. KONTINOS
NESC Chief Engineer at Ames Research Center (2006-07)

JULIE A. KRAMER WHITE
NESC Discipline Expert for Mechanical Analysis (2003-06)

NANS KUNZ
NESC Chief Engineer at Ames Research Center (2009-15)

STEVEN G. LABBE
NESC Discipline Expert for Flight Sciences (2003-06)

MATTHEW R. LANDANO
NESC Chief Engineer at Jet Propulsion Laboratory (2003-04)

DR. DAVID S. LECKRONE
NESC Chief Scientist (2003-06)

RICHARD T. MANELLA
NESC Chief Engineer at Glenn Research Center (2009-10)

JOHN P. MCMANAMEN
NASA Technical Fellow for Mechanical Systems (2003-07)

BRIAN K. MUIRHEAD
NESC Chief Engineer at Jet Propulsion Laboratory (2005-07)

DR. PAUL M. MUNAFO
NESC Deputy Director (2003-04)

STAN C. NEWBERRY
Manager, Management and Technical Support Office (2003-04)

DR. TINA L. PANONTIN
NESC Chief Engineer at Ames Research Center (2008-09)

JOSEPH W. PELLICCIOTTI
NASA Technical Fellow for Mechanical Systems (2008-13) and NESC Chief Engineer at Goddard Space Flight Center (2013-15)

DR. ROBERT S. PIASCIK
NASA Technical Fellow for Materials (2003-16)

DR. SHAMIM A. RAHMAN
NESC Chief Engineer at Stennis Space Center (2005-06)

DR. IVATURY S. RAJU
NASA Technical Fellow for Structures (2003-17)

RALPH R. ROE, JR.
NESC Director (2003-14)

JERRY L. ROSS
NESC Chief Astronaut (2004-06)

DR. CHARLES F. SCHAFER
NESC Chief Engineer at Marshall Space Flight Center (2006-10)

DAWN M. SCHAIBLE
Manager, Systems Engineering Office (2003-14)

STEVEN S. SCOTT
NESC Discipline Expert for Software (2003-05) and NESC Chief Engineer at Goddard Space Flight Center (2008-09)

BRYAN K. SMITH
NESC Chief Engineer at Glenn Research Center (2008-10)

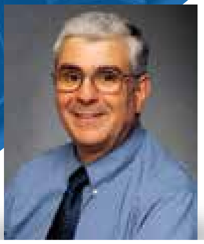
DR. JAMES F. STEWART
NESC Chief Engineer at Armstrong Flight Research Center (2005-14)

DANIEL J. TENNEY
Manager, Management and Technical Support Office (2009-13)

JOHN E. TINSLEY
NASA Headquarters Senior Safety and Mission Assurance Manager for NESC (2003-04)

TIMOTHY G. TRENKLE
NESC Chief Engineer at Goddard Space Flight Center (2009-13)

CLAYTON P. TURNER
NESC Chief Engineer at Langley Research Center (2008-09)



In Memory of **ROBERT A. KICHAK**

NESC Discipline Expert for Power and Avionics (2003-07)

Robert "Bob" Kichak, our colleague and friend, passed away in October 2017. Bob was a founding member of the NESC and our first NESC Discipline Expert for Power and Avionics (now known as NASA Technical Fellows). He was a valued member of our team and made numerous significant contributions to the NESC, Goddard Space Flight Center, and NASA. He will be remembered for his distinguished career and will be greatly missed.

NESC Alumni

Publications

Based on NESC Assessments and Reports

NESC Technical Papers, Conference Proceedings, and Technical Presentations

1. Barth, T.; Blankmann-Alexander, D.; Kanki, B.; Lilley, S.; and Parker, B.: Recurring Themes from Human Spaceflight Mishaps During Flight Tests and Early Operations. Human Space Flight Knowledge Sharing Forum, November 1-2, 2016, Huntsville, AL.

2. Bauer, J. E. and Richards, W.: Comprehensive Monitoring and Validation throughout the Aerospace Vehicle Life-Cycle using Fiber Optic Sensing Technology. 25th International Conference on Optical Fiber Sensors (OFS-25), April 24-28, 2017, Jeju, South Korea.

3. Beil, R. J.: Science of Test Workshop: Big Data Big Think. Science of Test Workshop, April 3-5, 2017, Springfield, VA.

4. Capadona, L. A.; Weiland, K.; Brady, T. K.; Holladay, J. B.; Rohn, D. W.; and Regenie, V. A.: Model-Based Systems Engineering Pathfinder. INCOSE 27th International Symposium, July 17-20, 2017, Adelaide, Australia.

5. Dawicke, D. S. and Raju, I. S.: Characterization of Elastic-Plastic Fatigue and Fracture Behavior in Thin Sheet Aluminum. iDICs 2016 Conference and Workshop/SEM Fall Conference, November 7-10, 2016, Philadelphia, PA.

6. Dennehy, C. J.: Workshop Overview & Future Navigation Landscape. SCaN/HEOMD Workshop on Emerging Technologies for Autonomous Space Navigation, February 16-17, 2017, WA, D.C.

7. Dennehy, C. J.: GN&C Lessons Learned and Associated Best Practices. ESA/ESTEC, June 6, 2017, Noordwijk, Netherlands.

8. Dennehy, C. J. and Wolf, A.: NASA Engineering & Safety Center (NESC) GN&C Technical Discipline Team (TDT) Activities Update. Aerospace Control and Guidance Systems Committee Meeting #118, October 19, 2016, Minneapolis, MN.

9. Emmons, D.; Mazzuchi, T. A.; Sarkani, S.; and Larsen, C. E.: Practitioner Checklist for the Aerospace Sector. Acquisition Research Journal.

10. Holladay, J. and Miller, S. T.: NASA's MBSE Pathfinder and New Community of Practice. NASA/JPL Symposium and Workshop on MBSE, January 25-27, 2017, Pasadena, CA.

11. Larsen, C. E.: Spaceflight Tragedies and Other Things to be Avoided. MEMS Seminar: Spaceflight Tragedies and Other Things to be Avoided, February 22, 2017, Durham, NC.

12. Larsen, C. E.: Structures in Space. 62nd Structural Engineering Conference, March 2, 2017, Lawrence, KS.

13. Larsen, C. E. and Irvine, T.: The NASA Engineering and Safety Center (NESC): Shock and Vibration Training Program. Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 20-22, 2017, El Segundo, CA.

14. Minow, J. I. and Pellish, J. A.: Space Environment Capabilities Leadership Team Activities (CLT). Spacecraft Anomalies and Failures Workshop, December 6-7, 2016, Chantilly, VA.

15. Minow, J. I. and Neergaard Parker, L.: Extreme DMSP Auroral Charging: Implications for Auroral Charging Benchmarks. 2016 American Geophysical Union Fall Meeting, December 12-16, 2016, San Francisco, CA.

16. Minow, J. I.: On-Orbit Detection of Spacecraft Charging Effects. In-Space Inspection Workshop, January 31-February 2, 2017, Houston, Texas.

17. Minow, J. I.: Challenges of the Space Environment in Low Earth Orbit and Beyond. Applied Space Environments Conference, May 15-19, 2017, Huntsville, AL.

18. Minow, J. I.; and Neergaard Parker, L.: NASA Use and Needs for Radiation and Spacecraft Charging Models. Presented at Space Environment Engineering and Science Applications Workshop, September 5-8, 2017, Boulder, CO.

19. Neergaard Parker, L.; and Minow, J. I.: Applied Space Environments Conference (ASEC) 2017 Summary. Presented at Space Environment Engineering and Science Applications Workshop, September 5-8, 2017, Boulder, CO.

20. Null, C. H.: Introduction to Human Measurement: Survey Design & Analysis. Science of Test Workshop, April 3-5, 2017, Springfield, VA.

21. Orr, J. S. and Dennehy, C. J.: Analysis of the X-15 Flight 3-65-97 Divergent Limit Cycle Oscillation. Journal of Aircraft, Volume 54, No. 1, January 2017, p. 135-148.

22. Prosser, W. H.: SHM Challenges for Spacecraft. 26th ASNT Research Symposium 2017, March 13-16, 2017, Jacksonville, FL.

23. Raju, I. S.; Dawicke, D. S.; and Hampton, R. W.: Some Observations on Damage Tolerance Analyses in Pressure Vessels. AIAA SciTech 2017 and Aerospace Sciences Meeting, 58th AIAA/ASCE/AHS/ASC, January 9-13, 2017, Grapevine, TX.

24. Rickman, S. L.; Iannello, C. J.; and Shariff, K.: Improvements to Wire Bundle Thermal Modeling for Ampacity Determination. Journal of Fluid Flow, Heat and Mass Transfer.

25. Rickman, S. L.; Richards, W.; Christiansen, E. L.; Piazza, A.; Pena, F.; and Parker, A. R.: Micrometeoroid/Orbital Debris (MMOD) Impact Detection and Location Using Fiber Optic Strain Sensing (FOSS). 6th Asia-Pacific Workshop on Structural Health Monitoring, December 7-9, 2016, Hobart, Australia.

26. Rickman, S. L.; Iannello, C. J.; and Shariff, K.: Improvements to Wire Bundle Thermal Modeling for Ampacity Determination. 3rd World Congress on Mechanical, Chemical, and Material Engineering, June 9-10, 2017, Rome, Italy.

27. Rickman, S. L.: Introduction to On-Orbit Thermal Environments. Thermal and Fluids Analysis Workshop 2017, August 21-25, 2017, Huntsville, AL.

28. Rickman, S. L.: Form Factors, Grey Bodies, and Radiation Conductances (Radks). Presented at Thermal and Fluids Analysis Workshop 2017, August 21-25, 2017, Huntsville, AL.

29. Rickman, S. L.: Introduction to Numerical Methods in Heat Transfer. Presented at Thermal and Fluids Analysis Workshop 2017, August 21-25, 2017, Huntsville, AL.

30. Rickman, S. L.: Introduction to On-Orbit Thermal Environments. Presented at Thermal and Fluids Analysis Workshop 2017, August 21-25, 2017, Huntsville, AL.

31. Russell, R. W.: Additive Manufacturing Certification. NASA Quality Assurance In Additive Manufacturing (AM), A Workshop On Assuring AM Product Integrity, October 11-12, 2016, Pasadena, CA.

32. Russell, R. W.: Supplier Issues Related to Additive Manufacturing Certification. 8th NASA Supply Chain Quality Assurance Conference, October 25-27, 2016, Greenbelt, MD.

33. Russell, R. W.: NASA Certification of Additive Manufacturing Parts and the Need for an Agency Standard. Aircraft Airworthiness & Sustainment (AA&S) 2017, May 22-25, 2017, Phoenix, AZ.

34. Russell, R. W.: NASA's Plans for Certification of Additively Manufactured Manned Spaceflight Components. NSMMS & CRASTE, June 26-29, 2017, Indian Wells, CA.

35. Schuster, D. M.: Recent Events in the Evolution of NASA's Aerosciences Capability. SciTech 2017, 58th AIAA/ASCE/AHS/ASC, January 9-13, 2017, Grapevine, TX.

36. Simpson, K. A.; Sarrel, M. A.; and Brady, T. K.: Verification and Validation Analysis and Visualization Tools Using MBSE. 2017 ASME Verification and Validation Symposium, May 3-5, 2017, Las Vegas, NV.

37. Squire, M. D.: Satellite Anomalies and Inferencing: Challenges and Uncertainties When Comparing Satellite Data to Risk Predictions. Spacecraft Anomalies and Failures Workshop, December 6-7, 2016, Chantilly, VA.

38. Swanson, D. and Dennehy, C. J.: Topic #3: An Introduction to the Fundamentals of Control-Structure Interaction. 40th Annual AAS GN&C Conference, February 5-10, 2017, Breckenridge, CO.

39. Vanzwieten, T. S.; Hannan, M. R.; and Wall, J. H.: Evaluating the Stability of NASA's Space Launch System with Adaptive Augmenting Control. 10th International ESA Conference on Guidance, Navigation & Control Systems, May 29-June 2, 2017, Salzburg, Australia.

40. Weiland, K. and Holladay, J. B.: NASA Model-Based Systems Engineering Pathfinder 2016 Summary and Path Forward. INCOSE International Workshop 2017, January 28-31, 2017, Torrance, CA.

41. Weiland, K. and Holladay, J. B.: Model-Based Systems Engineering Pathfinder. INCOSE 27th International Symposium, July 17-20, 2017, Adelaide, Australia.

42. West, T. S.; Annett, M. S.; and Womack, J. M.: Deterministic System Design of Experiments (dsDOE) Based Frangible Joint Design Reliability Estimation. Science of Test Workshop, April 3-5, 2017, Springfield, VA.

43. Wright, G.; Minow, J. I.; Neergaard Parker, L.; and Biesecker, D.: Maintaining Access to ACE Real-Time Solar Wind Data. Applied Space Environments Conference, May 15-19, 2017, Huntsville, AL.

44. Xapsos, M. A.; and Minow, J. I.: NASA Technical Fellow for Space Environments. Presented at 9th NASA Space Exploration and Space Weather Workshop, September 26-27, 2017, Greenbelt, MD.

NESC Technical Discipline Team Member Technical Papers, Conference Proceedings, and Technical Presentations

Avionics

1. Ladbury, R.: Strategies for SEE Hardness Assurance - From Buy-It-And-Fly-It to Bullet Proof. IEEE Nuclear and Space Radiation Effects Conference, July 17-21, 2017, New Orleans, LA.

Guidance, Navigation, and Control

1. Marsell, B.: Nonlinear Slosh Damping Data Analysis. Presented at Thermal and Fluids Analysis Workshop 2017, August 21-25, 2017, Huntsville, AL.

Human Factors

1. Nemeth, C.; Lay, E. A.; Blume, J.; Stephenson, J.; and Holbrook, J.: Using the RAG to Assess International Space Station Organizational Resilience. 7th Resilience Engineering Association Symposium, June 26-29, 2017, Liege, Belgium.

Loads and Dynamics

1. Blelloch, P. A.; Bremner, P.; Hutchings, A.; and Shah, P.: Validation of Methods to Predict Vibration of a Panel in the Near Field of a Hot Supersonic Rocket Plume. Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 20-22, 2017, El Segundo, CA.

2. Blelloch, P. A.; Hutchings, A.; Vold, H.; and Yoder, N.: Estimating Modal Damping From Operational Tests. Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 20-22, 2017, El Segundo, CA.

3. Irvine, T.: Statistical Energy Analysis Software & Training Materials, Part II. Spacecraft and Launch Vehicle Dynamic Environments Workshop 2017, June 20-22, 2017, El, Segundo, CA.

4. Kaplan, M. and Bremner, P.: Progress in Quantifying Uncertainty for Vibroacoustic Environments. Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 20-22, 2017, El Segundo, CA.

5. Kaufman, D; Gordon, S; Majed, A: Norton-Thevenin Receptance Coupling (NTRC) as a Payload Design Tool. Spacecraft and Launch Vehicle Dynamic Environments Workshop, June 20 -22, 2017, El Segundo, CA.

6. Majed, A.; Henkel, E.; Kolaini, A.; Vidyasagar, S.; and Bhatia, S.: Special Topics in Random Vibrations. Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 20-22, 2017, El Segundo, CA.

Structures

1. Chiu, J. and Brown, A. M.: Characterization of the Modal Characteristics of Structures Operating in Dense Liquid Turbopumps. ASME Gas Turbo Expo 2017, June 26-30, 2017, Charlotte, NC.

Systems Engineering

1. Neergaard Parker, L.: Surface Charging Overview. Presented at Space Environment Engineering and Science Applications Workshop, September 5-8, 2017, Boulder, CO.

NASA Technical Memorandums

1. Space Shuttle Program (SSP) Dual Docked Operations (DDO). **NASA/TM-2016-219350**

2. Modal Mass Acceleration Curve (MMAC) Loads Analysis Methodology. **NASA/TM-2016-219351**

3. Investigation of Unsteady Pressure-Sensitive Paint (uPSP) and a Dynamic Loads Balance to Predict Launch Vehicle Buffet Environments. **NASA/TM-2016-219352**

4. Multi-Purpose Crew Vehicle (MPCV) Crew Module (CM) Orbital Tube Weld Computed Radiography (CR) Assessment. **NASA/TM-2017-219368**

5. Composite Overwrapped Pressure Vessel (COPV) Liner Inspection Capability Development Assessment. **NASA/TM-2017-219369**

6. Buckling Analysis of the Space Launch System (SLS) Core Stage Ringless Cryotanks - Updated Buckling Load Predictions Based on As-Built SLS Cryotank Barrel Geometry. **NASA/TM-2017-219373**

7. Buckling Test Results and Preliminary Test and Analysis Correlation from the 8-Foot-Diameter Orthogrid-Stiffened Cylinder Test Article TA02. **NASA/TM-2017-219587**

8. Reaction Wheel Performance for NASA Missions: Bradford Engineering Reaction Wheel Unit Assessment. **NASA/TM-2017-219589**

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National Aeronautics and
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