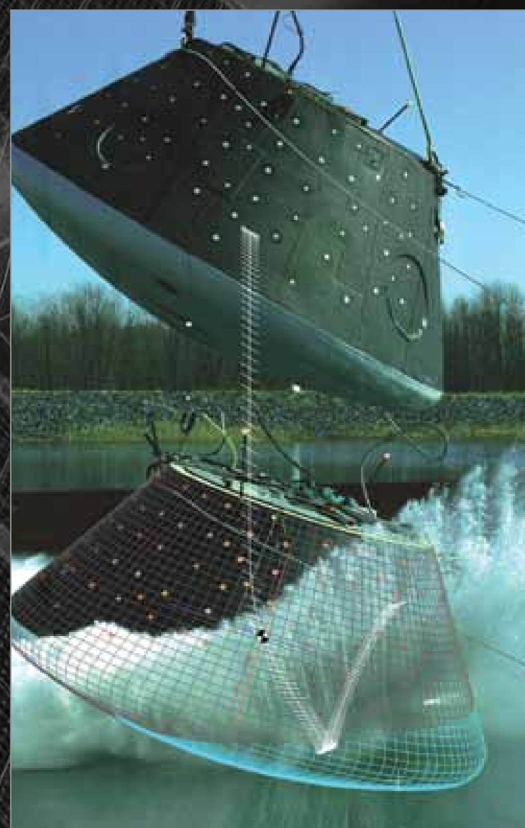
National Aeronautics and Space Administration

NESC

NASA ENGINEERING & SAFETY CENTER



2011 TECHNICAL UPDATE

www.nasa.gov

How to contact us

For general questions and requests for technical assistance visit us at:
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Welcome to the 2011 NASA Engineering and Safety Center (NESC) Technical Update

This past year has been a time of transition — marking the retirement of the Space Shuttle Program and the beginning of commercial crew partnerships and the new programs that will take NASA beyond Low Earth Orbit. The Agency continued to support the operation of the International Space Station and the development of numerous science spacecraft and aeronautic advancements. Along the way, the NESC has continued to provide ***independent test and analysis*** for critical areas across the Agency — whether it is in architecting a path for human exploration, selecting materials to be used in the next generation of spacecraft, or anomaly resolution for orbiting satellites. By providing a place for the Agency's engineering, science, and safety communities to turn to for independent technical expertise, the NESC is fulfilling our purpose of ensuring ***mission success through engineering excellence***.

In addition to highlighting the many contributions from the NESC's activities, we have featured some of the ***innovative techniques*** that have resulted from our assessments. Through the NESC's leadership, investments made in solving project-specific issues have been leveraged to provide lasting benefits to other current and future endeavors. ***Sharing the results and lessons learned*** from our activities is an important role for our organization.

The strength of the NESC model is the ***matrix support from the Centers,*** along with expertise from industry and academia. The NESC's success is made possible through the time and talent of these individuals, along with the support and cooperation of their home organizations. This year we are pleased to highlight just a few of the contributors to the NESC's multidisciplinary, multigenerational teams as part of the Center Focus section.

Through the dedicated efforts of our extended team of experts, the NESC remains committed to being a ***value-added resource*** for the Agency. We will continue to evolve and adapt to provide timely and relevant data and information for Agency decision makers. The NESC is pleased to provide this Technical Update for 2011.

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Cover: Left, shell buckling test preparation – page 29. Right, water impact testing of a boilerplate Orion crew module – pages 13,36,37.

The NESC Model

The NASA Engineering and Safety Center (NESC) employs the talents and diversity of NASA's workforce to ensure safety and mission success for NASA's high-risk programs. Within the framework of the NESC, hundreds of scientists and engineers from all 10 NASA Centers contribute to NESC activities each year.

The NESC is a part of NASA's Office of the Chief Engineer and is also closely affiliated with the Office of Safety and Mission Assurance. This arrangement allows independence, objectivity, and flexibility when working with other NASA organizations. The primary mission of the NESC is to ensure safety through engineering excellence by assembling technical expertise from across the country into focused teams, called assessment teams, to quickly address specific technical issues. The NESC has supported programs and projects throughout NASA and other federal agencies such as assisting with the Trapped Chilean Miner Rescue Operation and the National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation.

The NESC core team members are full-time NESC employees and form the nucleus of each assessment team. The core team provides the leadership, human and facility resource allocation, managerial support, and technical and cross-Center integration for each assessment. The NESC extended team is made up of the Technical Discipline Teams (TDTs), which represent a pool of engineering and technical talent. There are 18 TDTs, each one focusing on an engineering discipline, and most are led by a NASA Technical Fellow. The Technical Fellows are members of the NESC core team, while the TDTs are populated with engineers and scientists chosen for their technical knowledge and experience and drawn from NASA Centers, academia, industry, or other government

NASA\George Homich

NESC Director Mr. Ralph Roe Jr., left, and NASA Chief Engineer, Dr. Michael Ryschkewitsch.

agencies. When the assessment lead determines the requirements for the assessment, he or she will draw the appropriate personnel from the TDTs through the Technical Fellows.

One precept of the NESC is to provide justification and proof using data and documentation for decisions made by the NESC. All assessments conclude with a final report, which contains test results, analyses, findings, observations, recommendations, and lessons learned. Each report must be reviewed and approved by another unique element of the NESC: the NESC Review Board (NRB).

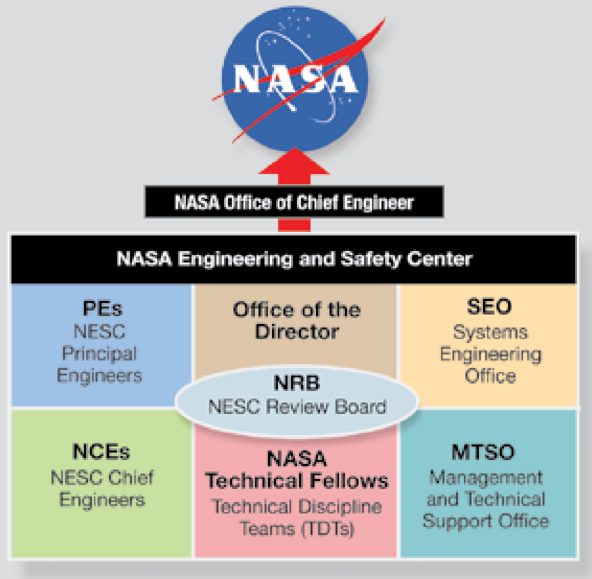
The NRB succeeds by using the principle that viewing an issue from different vantage points results in a more complete understanding. With this in mind, the members of the NRB come from all the offices of the NESC (core team) and represent all 10 NASA Centers and each of the TDT disciplines. Their diverse viewpoints and experiences result in a robust decision-making process in the NRB.

Engineers that participate in the NESC assessments gain a broader NASA-wide perspective, problem-solving experience, useful technical contacts, and are able to take this experience with them when they return to their home Centers. In fact, many of the core team members are not permanent and eventually return to their home Centers to apply lessons learned within their organizations. The NESC is also striving to ensure a productive and technically prepared workforce for NASA's future by integrating junior engineers into the NESC assessments. This concept began with the Resident Engineer Program, where early-career NASA employees were invited to join the NESC for 1-year detail assignments. This has evolved into a broader-reaching effort where junior engineers will be chosen to support individual assessments on a case-by-case basis, thus allowing more people the opportunity to work with the NESC and learn from the NESC members.

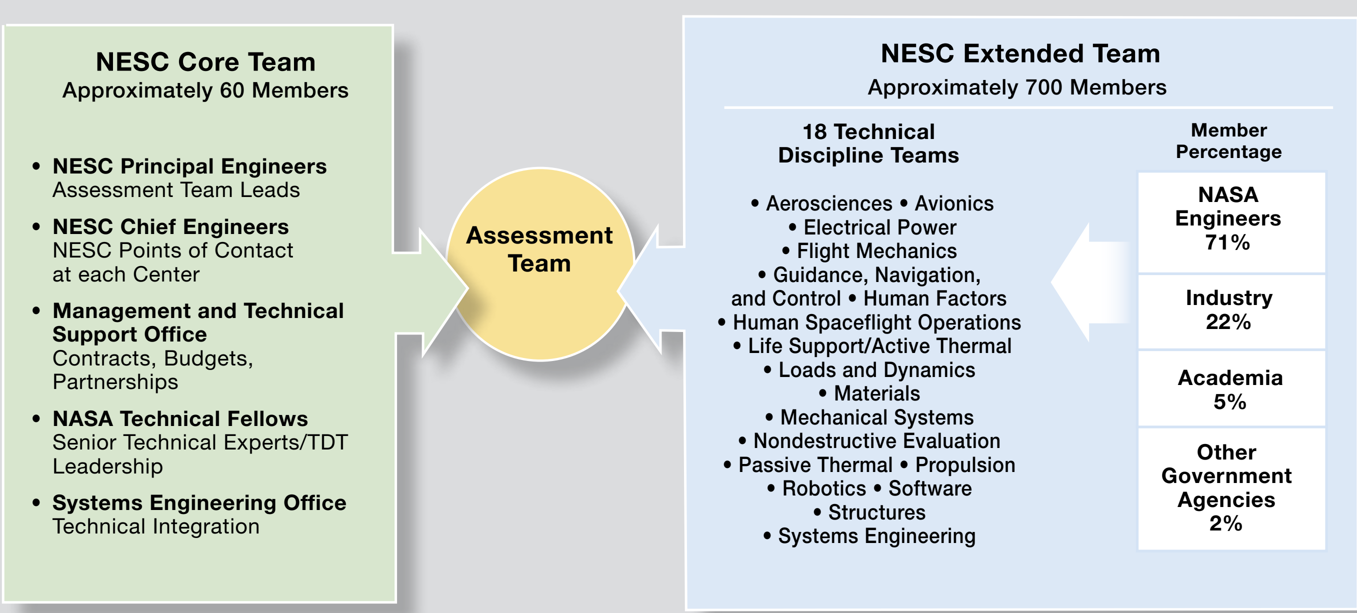
As NASA continues to push the boundaries of technology and exploration, the NESC contributes by providing a model that taps into the talented NASA workforce and capitalizes on the strength found in its diversity. This is as crucial for new projects and initiatives as it has been with mature operational programs like the Space Shuttle and the International Space Station.

For more information or to submit a technical request, contact the NESC online at nesc.nasa.gov.

The NESC Organization



The NESC Assessment Team Structure



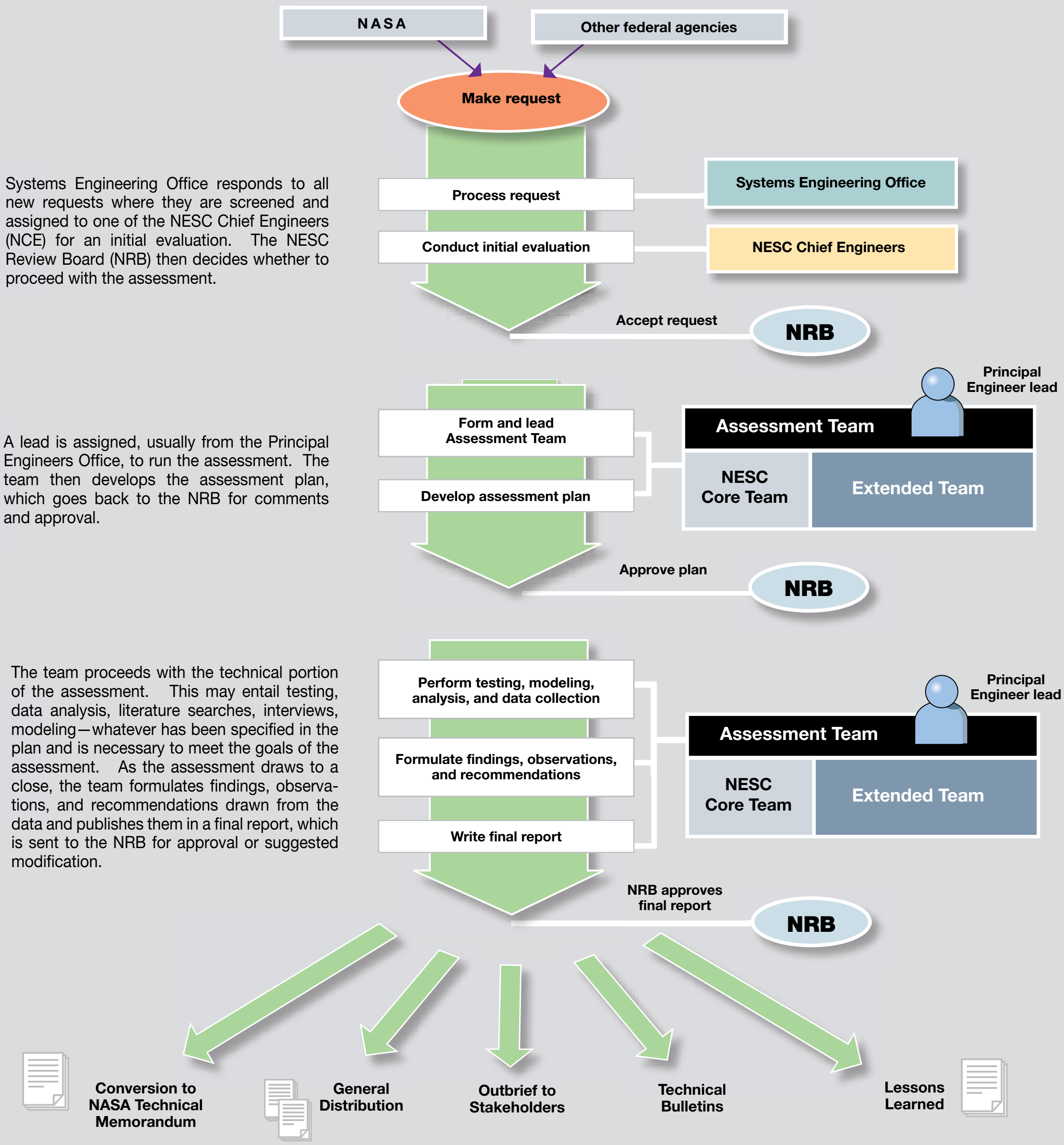
The Process for Finding Solutions to Difficult Technical Problems

Assessments form the structure and define the process the NESC uses to respond to requests and arrive at solutions to technical issues. The length of time an assessment takes, as well as the size of the assessment team, are highly variable. The process outlined below can be tailored to accommodate a given assessment.

1 Systems Engineering Office responds to all new requests where they are screened and assigned to one of the NESC Chief Engineers (NCE) for an initial evaluation. The NESC Review Board (NRB) then decides whether to proceed with the assessment.

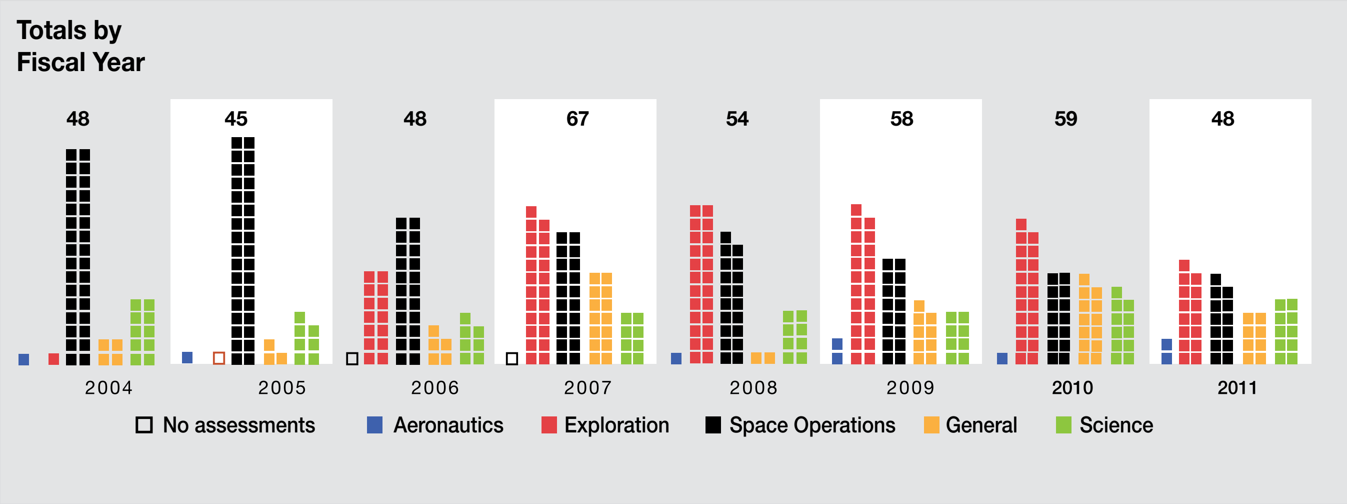
2 A lead is assigned, usually from the Principal Engineers Office, to run the assessment. The team then develops the assessment plan, which goes back to the NRB for comments and approval.

3 The team proceeds with the technical portion of the assessment. This may entail testing, data analysis, literature searches, interviews, modeling—whatever has been specified in the plan and is necessary to meet the goals of the assessment. As the assessment draws to a close, the team formulates findings, observations, and recommendations drawn from the data and publishes them in a final report, which is sent to the NRB for approval or suggested modification.

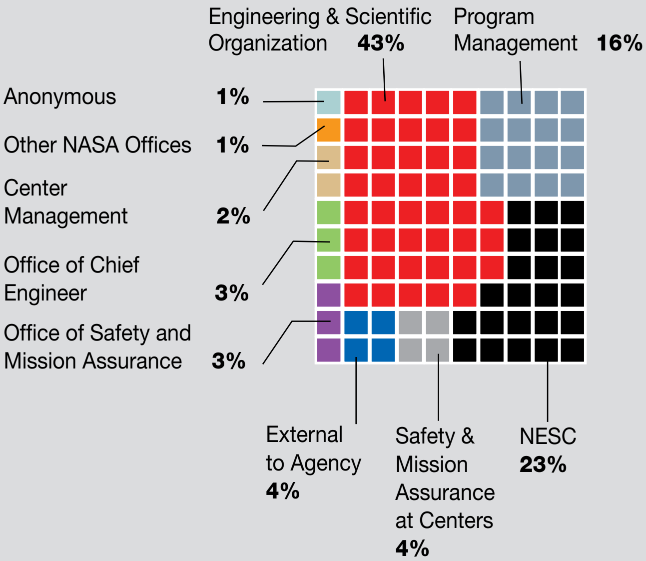


NESC Operational Statistics

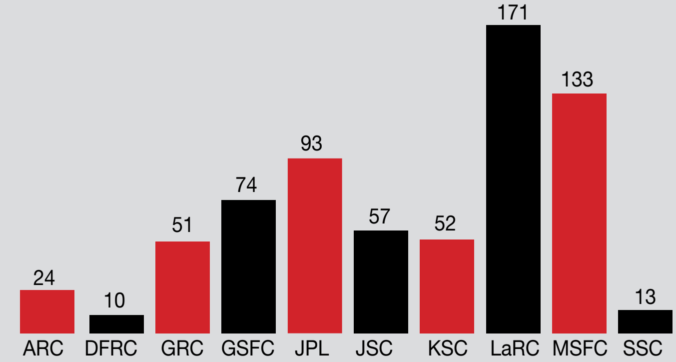
Accepted Requests by Mission Directorate: 427 Total



Source of Accepted Requests: 427 Total



Employees Supporting NESC Assessments



All statistics as of September 30, 2011

NASA Technical Fellows Contribute to Agency Activities

Over the past year, the 15 NASA Technical Fellows continued to serve as the senior technical experts for the Agency in support of the Office of the Chief Engineer and the NESC. As independent experts, their primary role is to resolve complex issues in their respective disciplines. Each Technical Fellow provided leadership for their Technical Discipline Team, which collectively form the technical backbone of the NESC.

Several NASA Technical Fellows directly contributed to the development of new space technology roadmaps for NASA's Office of the Chief Technologist, and all Technical Fellows participated in a comprehensive review of the complete set of 14 roadmaps. Responding to the Commercial Crew Program Office, the Technical Fellows defined appropriate space-system standards and requirements and also participated in industry partner subsystem design reviews.

As the stewards for their disciplines, they sponsored workshops and worked to ensure that lessons learned were incorporated into the Agency's engineering processes. Additionally, they performed state-of-the-discipline assessments for senior NASA decision makers. The NASA Technical Fellows have developed online Community of Practice sites on the NASA Engineering Network to capture and disseminate critical discipline historical knowledge before it is lost. They also developed short educational videos on discipline subtopics for the revamped NESC Academy.

NASA/Paul E. Alers

NASA Technical Fellow for Software, Michael Aguilar, talks with visitors at the Hispanic Heritage Month event at the National Air and Space Museum.

NASA/Ian Batchelder

NASA Technical Fellow for Avionics, Oscar Gonzalez, takes questions from Isabel Morales, CNN Español, at the Hispanic Heritage Month event at the National Air and Space Museum.

NASA Technical Fellows Conduct Thermal and Fluids Analysis Workshop

The NESC sponsored the Thermal and Fluids Analysis Workshop (TFAWS). This long-standing NASA-sponsored event was conducted at LaRC on August 15-19, 2011. With the continued support of the NESC Passive Thermal, Aerosciences, and Life Support/Active Thermal Technical Discipline Teams, this Community of Practice workshop covered active and passive thermal control, thermal protection, fluids, and aerothermal topics. Nearly 200 registered attendees participated in this year's workshop, including practitioners from industry, government, and academia representing NASA, the Department of Defense, as well as international participants. TFAWS participants met with thermal and fluids software vendors and attended a variety of activities, including short courses, software training sessions, and multiple paper sessions.

LaRC's Kaitlin Liles (right) and the multi-Center TFAWS Steering Committee organized this year's workshop, which featured thermal and fluids analysis tools training, paper sessions, and short courses.

The NASA Engineering Network home page nen.nasa.gov

Sharing Technical Expertise Through Communities of Practice

Since 2006, the NASA Technical Fellows, in conjunction with the NASA Engineering Network (NEN) team, have set up online Communities of Practice (CoP) to share technical knowledge across the Agency with the goal of improving the skill sets of its engineers and increasing collaboration across the Centers. The CoPs are part of the NEN and are accessible to anyone within the NASA firewall. Engineers can join and align themselves with a community, indicate their areas of interest, and appear on the contact list. Any user can find other engineers based on their area of interest. The past year has seen several major enhancements in the communities. The flight mechanics community added a library of portable dynamic models, all in a common industry standard format usable on most computer platforms. An engineer can pick up and quickly start to use a particular dynamic model. It is envisioned that other communities will adopt a similar online dynamic model library feature. Several communities also adopted "Ask an Expert," which is a feature that allows anyone at NASA to ask questions of vetted experts. Questions and answers are stored online so others can benefit from the exchange. The Technical Fellows encourage engineers to join the CoPs, contribute their individual knowledge, interact with peers, and get expert advice. Visit nen.nasa.gov.

The NESC Academy Goes Virtual

The NESC Academy continues to update its knowledge capture and delivery method to shorter, more easily accessible, and searchable online courses. A new website will be implemented in early 2012. Some of the features are highlighted below:

- Easily accessible short videos (approx. 15 minutes)
- Really Simple Syndication feeds (alerts when new videos are available)
- Full text searching (search content in the videos)
- Closed captioning

Training videos are available from multiple technical disciplines and feature:

- Discipline-specific training
- Lessons learned from NESC assessments

With the exception of the Innovative Engineering course, the original instructor-led academy courses are available online at http://www.nescacademy.org. These courses will also be available on the new site after it is deployed using the same URL: http://www.nescacademy.org.

The new video player features high-resolution, full-motion video; closed captioning with search; user-controlled layout; the ability to jump ahead by chapter or slide; and a zoom feature that allows magnification of any portion of the slide.

Technical Highlights

Exploration

Space Technology Roadmap Development Support

Problem: There has been a renewed focus on innovation and technology within NASA. This was primarily spurred by the 2011 NASA Strategic Plan's emphasis on the critical need for the Agency to invest in next-generation technologies and approaches to provide the advanced space technology base that is essential to NASA's achieving important goals in space exploration and science. Accordingly, the Office of the Chief Technologist (OCT) led an initiative to draft 14 space technology roadmaps (STRs), which lay out the time sequencing and interdependencies of high-priority advanced space technology research and development over the next 5 to 30 years.

NESC Contribution: The OCT requested the NESC assist in the STR development, each of which was to focus on a particular technology area. Several of the NASA Technical Fellows and others within the NESC organization contributed to this national endeavor by serving on the STR development teams in the following areas: communication and navigation systems; materials/structures/mechanical systems and manufacturing; thermal management systems; and entry, descent, and landing systems. Subsequently, once the draft STRs were released, the NESC performed a comprehensive and rigorous review of all 14 draft STRs, utilizing the Technical Fellows and their Technical Discipline Teams. The NESC STR review process focused on four primary areas: identification of technology gaps; integration across roadmaps (consistent with the Agency's Strategic Plan); prioritization of technologies; and quantitative ranking of technologies. In addition, the Technical Fellows have also been performing reviews of technology proposals received by OCT. Collectively, they have reviewed multiple game-changing technology white paper proposals and served on technology proposal review panels. NESC personnel were also involved with presentation of the draft roadmaps to the National Research Council panels.

Result: The NESC is playing an important role in the OCT's mission to ensure the required space technologies arein place to enable our future human and robotic exploration missions. In these multiple ways, the NESC is supporting NASA's return to its traditional role of being a technology innovator and, as such, a catalyst for national economic expansion, increasing the societal impact of our space program.

Development of Orion Crew Seat Energy Attenuation Mechanism Concepts

Problem: The Orion Multi-Purpose Crew Vehicle Program requested alternate seat attenuation designs be developed and analyzed for occupant protection in the Orion crew module (CM) with primary focus on providing improved crew survivability for nominal and contingency land landing (CLL). Due to the team's in-depth knowledge of the problem and work with isolation systems, the NESC had also been asked to evaluate design options in the crew seat area to mitigate the Ares I thrust oscillation (TO) environment and evaluate any effect on crew response to landing loads.

U.S. Navy

The thrust oscillation isolation system under test on two hydraulic shakers in the Environmental Dynamics Facility at the Naval Surface Warfare Center, Dahlgren Division, Virginia. (Right) Prototype isolation hardware.

NESC Contribution: The assessment team consisted of designers, analysts, test engineers from multiple Centers (including GSFC, JSC, GRC, JPL, and LaRC), contractors, academia, and other federal agencies. The team built, tested, and validated their concept for mitigating the launch vehicle TO event. Coupled loads models for launch (using Nastran), landing models with LS-DYNA, and Advanced Dynamic Analysis of Mechanical Systems multibody dynamics software were used to examine the optimal TO isolation frequency that would minimize crew loads during all phases of the Orion CM flight, and evaluate the system's response to the environment with this hardware in place. A series of component and system-level tests were completed to characterize hardware performance throughout all phases of flight.

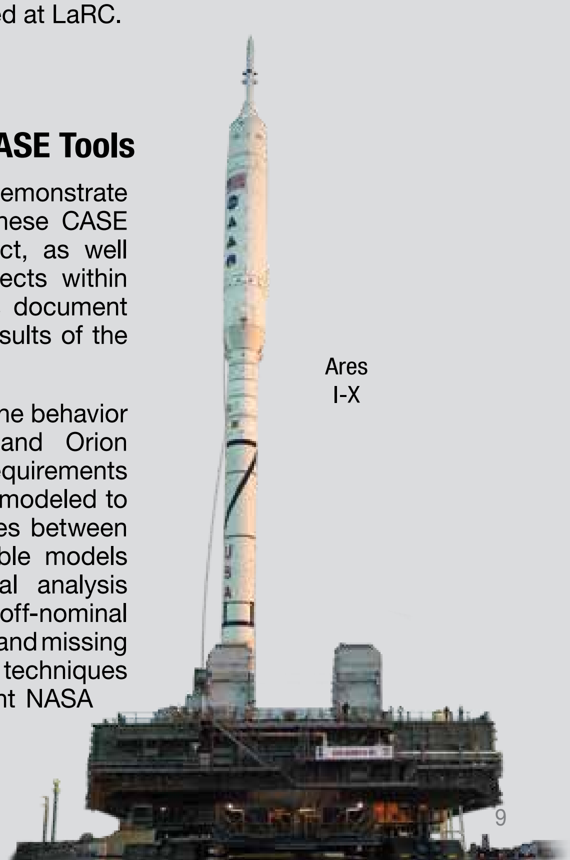
Result: The TO study confirmed the optimal crew isolation frequency and testing established the system performance and damping mechanism value. The NESC team found the pallet isolation approach to be appealing from a load mitigation perspective. Results indicated that the isolation system provided a reduction of dynamic load to about 20-30 percent of the input. It is important to note that without any isolation, there was dynamic amplification of about 125-150 percent of the input acceleration at the crew pallet. A design for locking out the isolators to prevent increased stroke during the landing event was also developed and evaluated during a series of system drop tests conducted at LaRC.

Mitigation of Software Development Risk Through the Use of CASE Tools

Problem: NASA initiated capturing system requirements at Levels 2 and 3 using Computer-Aided Software Engineering (CASE) tools in an effort to analyze the system behavior across the Ares launch vehicle and Orion spacecraft interfaces. Computer-Aided Design (CAD) tools perform a similar function for mechanical disciplines. An independent assessment was requested to capture the lessons learned and best use of these CASE tools for current and future projects.

NESC Contribution: The NESC is currently assessing the use of CASE tools within NASA. Phase I of this assessment entailed capturing the process and tools used by NASA and the Ares launch vehicle and Orion spacecraft system development teams. The CASE tool process success and gaps were identified, as well as the capabilities of the selected tools. Phase II will demonstrate best practices for the use of these CASE tools scoped to a single project, as well as scoped for use across projects within a major program. A guidelines document will be created to capture the results of the assessment.

Result: To capture and analyze the behavior of the Ares launch vehicle and Orion spacecraft interfaces, the text requirements for the abort requirements were modeled to analyze the communication states between the two. Building the executable models allowed automated and manual analysis and determined nominal and off-nominal behavior, incorrect requirements, and missing requirements. These modeling techniques can be directly applied to current NASA and commercial projects.

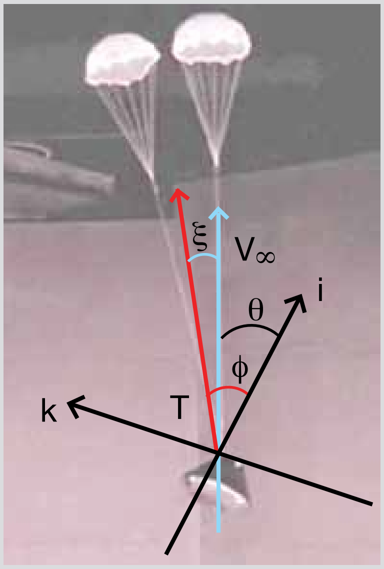


Ares I-X

Investigation of the Effects of Drogue Parachutes on Orion Crew Module Dynamics

Problem: In 2010, NASA successfully flew the Pad Abort-1 (PA-1) test flight that demonstrated the ability of the launch abort system to perform a pad abort and safely recover the Orion crew module (CM). During this flight, many vehicle and flight performance parameters were measured, including the ability of the parachute system to damp and otherwise arrest the vehicle's motion to ensure a safe recovery of the spacecraft and its astronauts. The parachute performance was predicted by project engineers prior to this test flight. Post-flight analysis of the data showed the flight-observed damping to be higher than preflight predictions. In addition, free-flight data acquired in the LaRC Vertical Spin Tunnel (VST) also predicted higher damping similar to flight data.

NESC Contribution: A group of former Apollo aerosciences experts teamed with the NESC and Orion Multi-Purpose Crew Vehicle (MPCV) Program personnel to study the CM drogue damping issue. This team reviewed the parachute performance prediction methods employed by the project and evaluated the wind tunnel test and PA-1 flight data. The team also reconstructed the prediction techniques used by the Apollo Program to predict drogue parachute performance. The flight and wind tunnel data were analyzed and compared with predictions performed using the Apollo legacy methodology, and the data were found to be in agreement.



Drogue resultant force acts in line with the free-stream velocity (red vector).

Result: The Apollo legacy methodology has been recovered and adopted by the Orion MPCV Program for their drogue parachute performance predictions. The NESC team also formulated additional VST testing to acquire necessary data for the legacy method to further validate its applicability and refine Orion CM drogue parachute performance predictions.

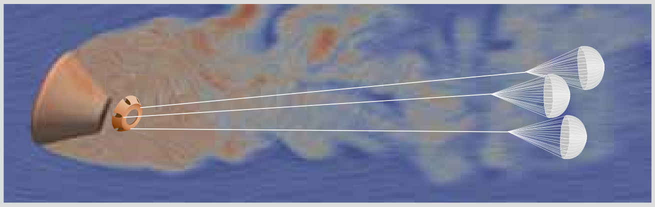
Lesson Learned: The Agency continues to identify engineering methods and practices developed during the early human space programs that are useful in predicting present vehicle performance and understanding new data. The recovery and documentation of these techniques are critical to mission success and efficient engineering design.

CPAS Wake Deficit Wind Tunnel Testing for MPCV-Class Spacecraft

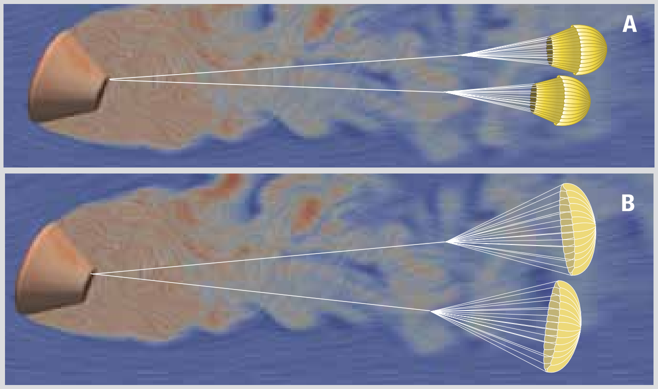
Problem: The Capsule Parachute Assembly System (CPAS) is used to decelerate the Orion Multi-Purpose Crew Vehicle (MPCV) crew module (CM) for landing during entry. The subsonic/transonic wake of the CM during heatshield forward descent interacts directly with the CPAS and is a critical factor that must be accounted for in the CPAS design. The aerodynamic character of the CM wake can have a significant impact on the deployment sequence and performance of the parachutes. Computational fluid dynamics (CFD) simulations play a key role in predicting the aerodynamic behavior of the wake since wind tunnel testing of CPAS concepts and configurations is costly and limited. However, below Mach 1, CFD prediction of the MPCV wake flow is questionable and thus leads to conservative design decisions. As a result, CPAS component designs can be oversized to account for uncertainty in the CFD-derived wake aerodynamics.

NESC Contribution: The NESC team is sponsoring an ambitious wind tunnel test at the ARC Unitary Plan Wind Tunnel to acquire detailed wake flow measurements behind a capsule model. The test will use particle image velocimetry in concert with more conventional test techniques to acquire high-fidelity unsteady flowfield data in the capsule wake. These data will be used to characterize the flowfield behind MPCV-class vehicles and as validation data for the CFD simulations used in the CPAS design. In addition to ARC, this study relies on multiple NASA Centers, including LaRC, JSC, and KSC, to assist in test formulation, model design and fabrication, and data acquisition and analysis. The model is being designed as a generic capsule so the data will be broadly available to the engineering community. The team is also collaborating with the Aeronautics Research Mission Directorate (ARMD) to supply data that can be used for advanced CFD method development sponsored by the ARMD.

Forward bay cover parachutes



Crew module drogues, reefed (A) and inflated (B)



CM wake visualization from CFD analysis with locations of CM drogues overlaid.

Result: Initial results are expected in 2012 with initial report to stakeholders at that time.

Continuation of Launch Abort System Risk Mitigation Efforts

The NESC has continued to build on the successful Max Launch Abort System (MLAS) flight test of July 2009 with analytical work on a flight-like “objective” system and early design of a follow-on flight test vehicle. Launch abort is a safety-critical technology crucial to future human launch vehicles and, as such, a key element in the success of commercial crew providers. It is in NASA’s interest to ensure alternate launch abort technologies are explored, both to mitigate the development risk associated with government and commercial launch vehicles and to develop the in-house expertise necessary for the acquisition of commercial systems. Analytical work has narrowed the tradespace to an all-propulsive system with active guidance that is effective through all abort regimes, built on lessons learned and data derived from the MLAS flight. This conceptual design is based on requirements set for the Orion launch abort system and is expected to envelop those of commercial interests. A baseline concept for a vehicle suitable for demonstrating the all-propulsive concept in flight has been completed, with design analysis ongoing. Key risks have been identified, and separate mitigation projects are underway. The core development team is drawn from across the Agency and structured to provide hands-on practical experience for early-career team members under the guidance of seasoned mentors, including NASA Technical Fellows.

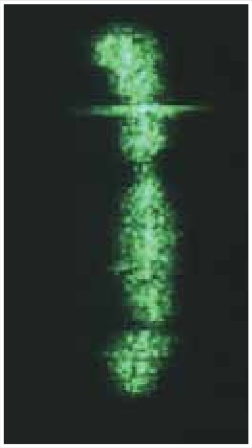
An MLAS objective system configuration undergoing wind tunnel test at LaRC’s Transonic Dynamics Tunnel.

Probability of Detection Limit Implementation on Orion CM Propellant Tank

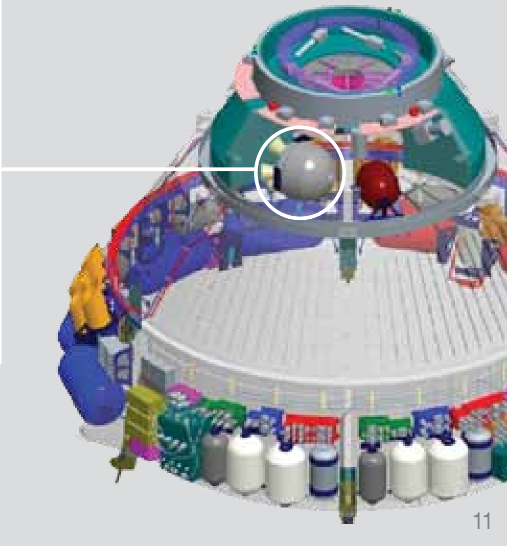
Problem: To lower mass, propellant tanks for the Orion crew module (CM) were designed with reduced wall thickness. Fracture analysis resulted in the requirement that the liquid penetrant nondestructive evaluation (NDE) method used to inspect these tanks be capable of finding flaws smaller than the 0.050-inch limit previously used in the Orbiter Fracture Control Plan (OFCP). Although this limit was formally removed with the adaptation of NASA-STD-5009, Nondestructive Evaluation Requirements for Fracture Critical Metallic Components, there have been lingering concerns about using penetrant inspection for detecting smaller flaws. The tank vendor’s inspectors passed the required probability of detection (POD) demonstration test for the smaller flaw sizes using fatigue cracked flat panel test coupons. However, JSC engineering recommended that the 0.050-inch detection limit still be used or that the vendor repeat the demonstration tests under more representative conditions. The NESC NDE Technical Discipline Team (TDT) was requested to provide an opinion on this recommendation.

NESC Contribution: Experts from the NESC NDE TDT reviewed a variety of data relative to the capability of penetrant methods. They compared recent penetrant POD testing performed by GSFC to results obtained in the OFCP test program. They also examined testing that showed the detrimental effects of changes in specimen orientation and geometry on penetrant POD test results. Also reviewed were reports that showed the effects of other factors, such as material, surface finish, inspection area, and penetrant materials, as well as the limits used for penetrant inspections by the U.S. Air Force.

Result: After this data review, the NESC NDE TDT concurred with the recommendation to use the 0.050-inch limit or repeat the demonstration tests under more representative conditions. As a result, the wall thickness was increased to accommodate the 0.050-inch detection limit. However, additional demonstration tests under more representative conditions are being planned as this issue also applies to composite overwrapped pressure vessel liners being developed for the Orion CM.



Penetrant indication for tightly closed (0.088-inch) fatigue crack in a propellant tank.



Exploration Flight Test-1 Radiometer Feasibility Study

As NASA moves toward space exploration beyond Low Earth Orbit (LEO), spacecraft atmospheric entry velocities can be over twice that experienced by the space shuttle. At these speeds, the entry heating can be dominated by shock layer radiation, a heating component which is not as important for LEO trajectories and one that is not easily or accurately described with present engineering models. Physics-based radiative heating prediction methods have been developed to overcome some of these issues but require flight data for method validation. In-flight radiometer measurements are needed to obtain data traceable to flight conditions. The Orion Multi-Purpose Crew Vehicle Program has undertaken a study to determine the feasibility of implementing radiometers into the Exploration Flight Test-1 heatshield. The NESC performed a complementary assessment to evaluate optical system and thermal performance and devised a ground calibration test plan for the flight radiometer system. As a result of the study, design changes and material substitutions were recommended and a design-of-experiments-based test matrix, using both arc jets and solar thermal facilities, was developed. Augmentation of the current design was considered, and design alternatives were also provided.

Illustration of Orion CM during re-entry.

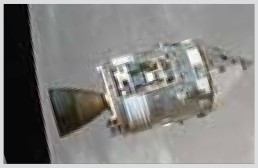
Orion Crew Module Thermal Protection System Margin Study

Problem: The Orion Multi-Purpose Crew Vehicle relies on an ablative heatshield thermal protection system (TPS) to protect the crew module (CM) and its crew during re-entry. This critical component must be designed with enough margin to ensure safe return yet be efficient in mass and thermal performance. The heatshield thickness determination process must account for three uncertainty sources: trajectory dispersions, aerothermal environment predictions, and ablator material property effects. The first two sources affect the applied heating environment, and the last affects the resulting bond line temperature at the ablator-structure interface. The bond line temperature margin currently employs a temperature reduction derived from the TPS Advanced Development Program (ADP) era, where it was based on Phenolic Impregnated Carbon Ablator data and analysis from the Stardust Program. However, the CM will utilize a different ablative heatshield material (Avcoat). Additionally, the carrier structure has changed significantly from the ADP era, resulting in a reduced allowable bond line temperature. The CM heatshield must also be built with higher reliability than the Stardust heatshield.

NESC Contribution: The objectives for the NESC's Orion TPS Margin Study were to determine the effect of analysis parameters and system-level uncertainties on the TPS heatshield thermal design reliability, determine the design reliability of the current heatshield design, and provide recommendations for efficient Avcoat ablator arc jet testing.

Result: The work was completed resulting in a design-of-experiments-based arc jet test matrix that was successfully employed during a recent ablator arc jet testing campaign. Additionally, the team completed development of a heatshield reliability model and identified model sensitivity to input parameters.






The Mercury, Gemini, Apollo, and Space Shuttle Programs made different determinations on when it was appropriate to fly a crew for the first time.

Determining Readiness for First Crewed Flight of New Spacecraft

The NESC was requested to develop a framework to help Agency leadership and program decision makers determine when to allow crewmembers to fly on a new human spaceflight system for the first time. Because specific approaches and designs may vary significantly, prescriptive instructions or thorough checklists cannot be developed to apply to all possible human spacecraft systems. The decision on first flight with a crew is ultimately a judgment call by the program and Agency leadership. To aid decision makers, the NESC team developed a generic framework for evaluating whether any given program has sufficiently complete and balanced plans in place to allow crewmembers to fly safely on a human spaceflight system for the first time.

Orion Crew Module Water Impact Testing and Modeling

Problem: The Orion Multi-Purpose Crew Vehicle (MPCV) Program lacked development test data to anchor the LS-DYNA analytical model predictions of crew module (CM) water landing loads prior to the program's critical design review. These loads are the largest structural mass design driver and were predicted by modeling the physical interaction of the heatshield and sidewall structures over a large range of water landing conditions. Consequently, the CM structure may have been oversized and too heavy, or undersized, presenting a development risk or a crew safety risk. In addition, no best practices existed for this application in NASA and water drop tests were not planned by the program until mid-2011.

NESC Contribution: An opportunity was identified in late 2009 to quickly modify an existing full-scale boilerplate CM and use it as a pathfinder for the Orion MPCV Program's water drop tests using only the variables of vertical velocity and entry angle. The NESC water drop test data was compared to model predictions to provide an early assessment and data set to inform the program's structural design team. The NESC team included contract consultants (including retired Apollo engineers) and civil servants (including early-career engineers) from DFRC, GRC, GSFC, JPL, JSC, KSC, LaRC, WFF, and the U.S. Army and Navy. The test, analysis, and data evaluation was conducted in two phases over a 2-year period. The first test phase in February 2010 comprised 18 vertical drops at 4 water entry conditions using a crane and a test facility at the U.S. Army's Aberdeen Test Center (ATC) in Maryland. Onboard instrumentation included accelerometers and inertial measurement units. Photometric targets on the CM surface allowed high-speed cameras to capture imagery that was processed post-test to characterize the CM position and attitude during the water entry. Predictions of acceleration response and sensitivities to initial conditions were generated using the LS-DYNA model at all test conditions and using the program's existing fluid mesh and modeling parameters. For the second phase of testing, the CM was modified to add heatshield and sidewall-pressure sensors and internal strain gages on the primary structure load path. Forty-one drops at 21 conditions were completed at ATC in March 2011. The LS-DYNA accelerometer, pressure, and strain predictions were generated at key test conditions using the program's settings and for a limited number of other models and other settings.

Both phases of water impact testing were completed at the U.S. Army's Aberdeen Test Center, Maryland.

Result: Acceleration test measurements were significantly smaller than initial LS-DYNA predictions. The correlation improved when water and structure finite element mesh sizes were increased, and the contact model for characterizing fluid-structure interaction was initialized with test data. The Orion MPCV Program's modelers and structural design engineers benefited directly from this finding as landing loads and uncertainties were reduced. After accelerated analysis of the second phase of test data in 2011, preliminary results were provided to the program's structural designers and analysts; LS-DYNA modelers; guidance, navigation, and control (GNC) system designers; and drop test planners. The timely briefings and test data helped the program validate the Exploration Flight Test-1 CM landing safety margins, reduce the mass of the Orion CM, and improve the landing GNC logic design. The program's water drop test team also benefited from NESC testing lessons learned. A detailed analysis and comparison of the test data with LS-DYNA predictions will be completed by March 2012.

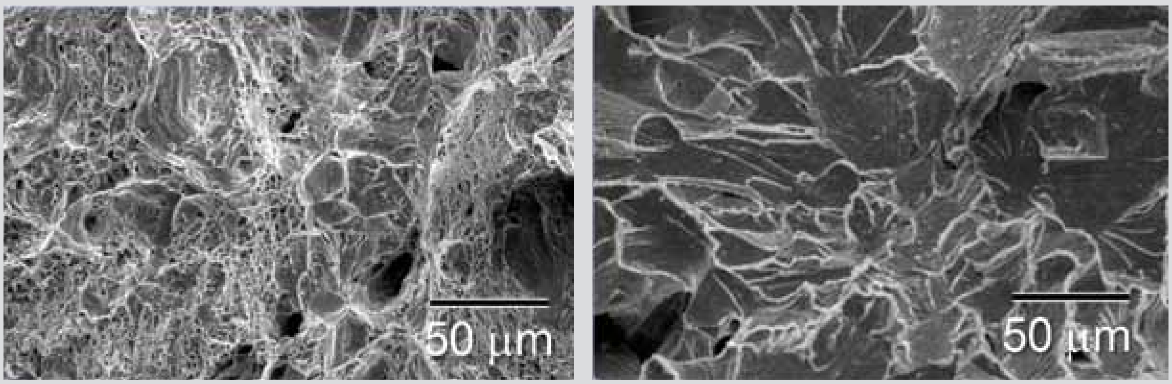
Shock Test Specifications for Reusable Equipment

Space Exploration Technologies Corp. (SpaceX) is in the process of qualifying their electrical and mechanical components for various shock environments, including pyrotechnic, mortar firing, and water impact. The NESC was asked to share NASA's experience with qualifying hardware for the Space Shuttle Program and other programs. The Space Shuttle Solid Rocket Booster (SRB) Project has extensive experience in this area. A white paper describing their experience has been written and released. Communications between the NESC members and SpaceX have taken place to share ideas and answer questions about NASA experiences. NASA documentation on this subject has also been provided to SpaceX.

The SpaceX Dragon capsule at KSC.

High-Strain Rate Testing of Reaction Control Thruster C-103 Alloy

In June 2010, a test firing of an orbiter reaction control system (RCS) thruster at JSC's White Sands Test Facility resulted in a brittle cleavage fracture of the C-103 alloy (89 percent niobium — 10 percent hafnium) thruster chamber. The failure analysis related the brittle thruster fracture mode to a high-strain rate phenomenon reported in the literature. Because there are no C-103 data relative to the important ductile-brittle behavior and C-103 will likely be used for Orion Multi-Purpose Crew Vehicle thrusters and other future applications, the NESC conducted high-strain rate tests to gain first-of-kind data for C-103. An impact test was developed to achieve the required high-strain rate to confirm the ductile-brittle transition in C-103. The C-103 transition occurred at an extremely low temperature (-160 C) compared to the pure niobium literature finding of -50 C. The C-103 data do not fully explain the RCS thruster room temperature cleavage fracture mode. Further testing will be required to gain additional understanding of brittle fracture in this complex C-103 alloy and confirm other damage modes, such as embrittlement, are not the root cause for cleavage at room temperature.



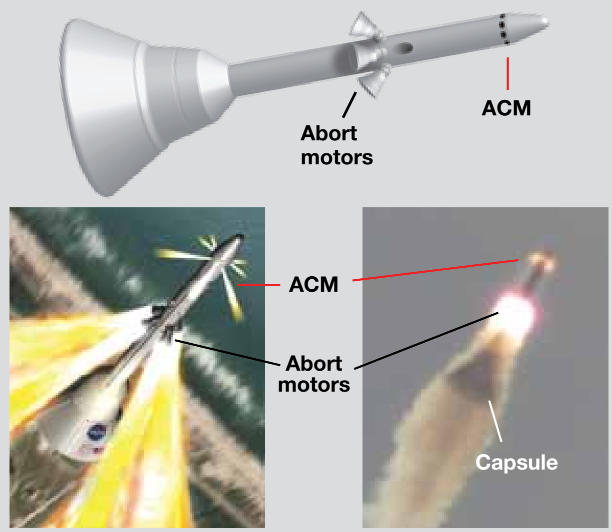
Alloy C-103 fracture surfaces: Micrograph shows ductile (left) and brittle (right) — dark areas are flat cleavage regions.

Carbon-Carbon Silicon Carbide (C/C-SiC) Material Characterization

Problem: The Orion launch abort system (LAS) contains an attitude control motor (ACM). The purpose of the ACM is to safely steer the capsule away from the launch vehicle and orient the capsule for parachute deployment. The ACM contains eight exhaust nozzles equally spaced around the upper portion of the LAS. The motor automatically steers the LAS/capsule by controlling the thrust produced by each nozzle; this is accomplished by rapidly adjusting the opening of the eight valves and controlling the exhaust flow of the hot/expanding combustion gases. Each of the eight valves consists of two critical components: the pintle and the pintle guide, which are fabricated from an advanced composite material consisting of woven carbon (C) fibers and a silicon carbide (SiC) matrix (C/C-SiC). Due to the complex woven architecture of C/C-SiC and exposure to an extreme operating environment (high pressure and temperatures greater than 3000 F), a thorough understanding of material properties is required to ensure a reliable ACM design. An independent technical evaluation of C/C-SiC material properties was requested by the Orion Multi-Purpose Crew Vehicle Program.

NESC Contribution: The NESC team of materials/structures/nondestructive evaluation (NDE) discipline experts from JSC, LaRC, and academia, with the full support of multiple organizations (LaRC and MSFC project engineering and Lockheed Martin Corp.; Alliant Techsystems, Inc.; and Fiber Materials, Inc.), conducted a thorough review of the C/C-SiC database. The purpose of this phase I effort was to understand the maturity of the C/C-SiC relative to properties, modeling, NDE methods, and component testing. As a result of the independent review, a phase II testing plan was developed to expand the current materials database.

Result: The phase II building-block approach will use simple test methods that simulate first-order loads and pintle/guide failure locations. The approach will develop a key understanding of nonlinear material properties required for the breakload-design margin approach, assist in validation of the current model, develop NDE methods, and develop simple test methods that will be used by the LAS development team.



Orion launch abort system in operation.

Review of Shuttle Carrier Aircraft Air Loads for Phantom Ray Ferry Flight

Boeing Phantom Works is developing an unmanned air vehicle (UAV) known as the Phantom Ray. The prototype for this new aircraft design was developed and fabricated in St. Louis, Missouri, and had to be transported to Edwards AFB, California, for its flight test program. Boeing proposed using NASA's Shuttle Carrier Aircraft (SCA) to transport the aircraft and developed support hardware to facilitate mounting the Phantom Ray on the SCA. This hardware added significant aerodynamic blockage to the basic SCA mounting hardware, and there was concern that the unsteady flowfield generated by this hardware could adversely impact the aft fuselage and tail structure of the SCA. Due to budget and schedule constraints, performing a comprehensive ground or flight test campaign on the baseline and modified SCA was not feasible. Boeing planned only one test flight with the UAV attached before the long ferry flight to California. The NESC conducted unsteady pressure and acceleration measurements on the SCA aft fuselage and tail during this flight to determine if the induced unsteady flowfield would cause high structural vibrations and potential tail damage. The test data showed no significant increase in structural vibrations, and the Phantom Ray was successfully ferried to Edwards AFB where it is undergoing flight tests.

Boeing photo/Ron Bookout

Boeing's Phantom Ray unmanned aircraft system technology demonstrator became a paying piggyback passenger on NASA's SCA for its ferry flight from St. Louis to Edwards AFB.

Assessment of the SSP Approach to STS-135 with Soyuz Crew Rescue

NASA's Associate Administrator for Space Operations requested an independent assessment of the proposed mission approach to STS-135 using Soyuz for crew rescue. The independent review focused on assessing any change in the risk exposure to the STS-135 crew as compared to previous space shuttle missions since Return to Flight (RTF). The following aspects were specifically addressed by the review team: retention of critical space shuttle personnel, space shuttle vehicle processing, International Space Station (ISS) supportability, medical considerations, probabilistic risk assessment, crew selection and training, and crew rescue and return. The plan assessed by the NESC was considered feasible and within the scope of crew and ISS systems capabilities and provided an adequate mitigation approach for identified risks. The risk associated with the STS-135 crew rescue scenario using Soyuz vehicles was within the family of other space shuttle crew rescue risk assessments since RTF. The assessment team submitted 18 recommendations for consideration to further mitigate risks associated with the program's plan. Both the Space Shuttle and ISS Programs successfully implemented 16 of 18 recommendations prior to STS-135, with the remaining recommendations requiring implementation only if a contingency shuttle crew support scenario occurred.

The Russian Soyuz (top left) is docked to the ISS with Space Shuttle Atlantis docked (right) during the STS-135 mission.

Vision Navigation System Flight Experiment Development

A notional representation of the VNS flash LIDAR illuminating the ISS to determine range and bearing relative navigation information.

Problem: The NESC, responding to the need to develop and mature guidance, navigation, and control (GNC) component technology, initiated a technical assessment in November 2010 to perform a risk-reducing technology demonstration of an advanced version of the Orion crew module vision navigation system (VNS). The VNS is a flash light detection and ranging (LIDAR) relative navigation sensor used during spacecraft rendezvous. Mounted on a "chaser" spacecraft, the VNS pulses its laser to determine range and bearing relative to optical reflectors mounted on a vehicle that is the rendezvous "target." This is accomplished by measuring the time of flight of a laser pulse to the target and reflected back to a detector.

In a flash LIDAR system, the laser beam is diverged so that the illuminated spot on the target surface closely matches the field of view of the two-dimensional detector array. Each pixel in the detector array is individually triggered, allowing for a measurement of both intensity and time of flight (i.e., range) of the returned laser pulse. Thus, for a single laser pulse, all pixels in the scene are illuminated, with each pixel providing range and intensity information. This results in the generation of a full topographic and intensity map of the entire scene with each VNS laser pulse.

This GNC technology demonstration, called the vision navigation sensor autonomous rendezvous and docking (AR&D) relative navigation experiment (VADRE), was a collaborative risk mitigation effort between the NESC, the Orion Multi-Purpose Crew Vehicle Program, and the NASA AR&D Community of Practice (CoP). The VADRE unit is a follow-on and more capable sensor than the sensor test for Orion relative navigation risk mitigation (STORRM) VNS unit. STORRM was demonstrated on-orbit during shuttle mission STS-134 in May 2011. The VADRE unit includes new high-performance microprocessors which host flight software executing sophisticated image processing algorithms. These new embedded algorithms, first developed for VADRE, perform pixel processing (e.g., centroiding), target processing, sensor configuration and control, and limit monitoring functionalities.

NESC Contribution: The VNS was baselined as the primary rendezvous, proximity operations, and docking sensor for the Orion spacecraft. As part of the NESC GNC technical assessment, the VADRE unit has been assembled at Ball Aerospace and Technologies Corp. (the sensor technology provider) from “as-built” engineering development unit electronic boards and optical/laser subassemblies developed for the Orion spacecraft and subsequently transferred to the NESC. Once assembly was completed, the VADRE unit was functionally tested and then system-level calibrated. The VADRE unit has a wide operational range, from 5 kilometers to 2 meters. Optical performance was tested and verified against multiple known and well-characterized targets spanning this operational range.

Result: Following the completion of its testing in September 2011, the VADRE unit has become an asset for the NASA AR&D CoP. The NESC delivered VADRE to the Satellite Serving Capabilities Office at GSFC for integration into their Argon AR&D ground test bed. There the unit was thoroughly exercised in a series of AR&D ground-technology demonstrations.

The data collected from VADRE has been made available to the Agency-wide AR&D CoP, where it is being carefully analyzed and evaluated. Also, in parallel with the VADRE ground demonstrations, plans are being formulated by the AR&D CoP to fly this unit to the International Space Station (ISS). Collaborative demonstrations of the VADRE on ISS over a period well beyond that of the relatively short STORRM VNS flight test, will serve to validate relative navigation and vehicle position estimation algorithms in a realistic operational environment over a broad range of dynamic and lighting conditions.

Standard Requirements for Fire Protection Systems on Crewed Spacecraft

Problem: In response to NASA and external recommendations, the fire protection systems aboard the International Space Station (ISS) are being upgraded. While developing a filtering respirator and a fine water mist portable fire extinguisher, the ISS technical teams identified a need for additional requirements for fire protection systems and environments. Specifically, ISS needed a set of standard requirements to help design firefighting hardware and define common environments and procedures for testing and certifying new firefighting systems. The standard requirements should also apply to future crewed spacecraft.

An ISS Expedition 20 flight engineer conducts an inspection on portable fire extinguisher and portable breathing apparatus equipment.

NESC Contributions: An initial team of experts from around the Agency was formed and has begun working on standard requirements. A list of personnel outside NASA with expertise in emergency response and developing standards was also compiled. The intent is to engage some of these experts in the development of the technical content for the standard requirements. The NESC representatives will support peer reviews of the fire extinguisher test plan and the technical content for new design requirements for fire protection systems. The NESC is also providing statistics expertise to support the development of baseline test configurations, test data reduction and analysis, and fire extinguisher optimization.

Result: Instead of developing a new NASA standard, an approach to update the existing fire protection system section of NASA-STD-3001, Volume II (Human Factors, Habitability, and Environmental Health), and to add a new section to the Human Integration Design Handbook was adopted. A separate handbook specifically for portable fire extinguishers may be developed. The team is developing technical content for the standard and the handbook. Clearly documented requirements, rationale, test plans, and best practices from one generation of spacecraft systems help prevent "reinventing the wheel" when upgrading those systems on existing spacecraft as well as designing new systems for future crewed spacecraft.

Pyrovalve Reliability Assessment for Expendable Launch Vehicle Payloads

Problem: Single operation pyrotechnically operated valves (pyrovalves) perform critical propulsion system functions for payloads onboard expendable launch vehicles (ELVs). When hazardous propellants such as hydrazine (N_2H_4) or nitrogen tetroxide (N_2O_4) are used, concerns increase for the safety of personnel when they are working near the payload. Additionally, payload safety reviewers and spacecraft programs have not always agreed on the number of mechanical inhibits that pyrovalves represent nor on the credibility of leakage as a failure mode. These issues, and how control systems and software inhibits are implemented, have caused concerns and changes to spacecraft systems late in the launch-processing flow.

NESC Contribution: An assessment by subject-matter experts is under way to give clearer guidance for evaluating pyrovalve mechanical integrity, risk of inadvertent ignition, and overall reliability of the valve and control systems.

Result: A draft set of minimum requirements for manufacturing and testing has been developed. Potential leak paths in parent-metal pyrovalves have been evaluated with finite element analysis (FEA). Leakage was deemed not credible for the common ⅜-inch, ½-inch, and ¾-inch models studied to date. Nondestructive evaluation also helped validate the FEA on the ¾-inch model and showed that the configuration was robust. The ¾-inch valve has a maximum expected operating pressure of 750 pounds per square inch gauge (psig) and no evidence of deformation was measured after being subjected to 3600 psig. Evaluation of mechanical integrity for other pyrovalve models, risk of inadvertent operation, and reliability of pyrovalves and controls is in progress. The assessment will provide guidance to assist the ELV payload safety community in developing payload safety policies regarding pyrovalves.

John Anderson (left) and Steve Woods of WSTF discuss a pyrovalve stress analysis, performed to evaluate safety margins.

Space Operations

Microphone Phased Array for Measuring Launch Vehicle Lift-off Acoustics

The acoustics generated during the lift-off of a launch vehicle have historically been characterized via single-point sensors, which provide acoustic levels at discrete points. A microphone phased array has the potential to measure acoustic levels over the entire launch pad and vehicle. The NESC is conducting an assessment to develop and demonstrate this capability. This year, acoustic data collection with a phased array on the subscale Ares I liftoff acoustic test article was completed. Preliminary data analysis shows that, the array can survive repeated exposure to the harsh liftoff environments and that with proper array design, the acoustic sources of primary interest can be mapped with a single microphone array. Opportunities to demonstrate the technique on a full-scale launch vehicle are being pursued.

(From left) Robert Mosher, Roberto Garcia, and Jayanta Panda in front of the acoustic phased-array sensor tower, viewing the Ares I scale launch vehicle and launch pad model.

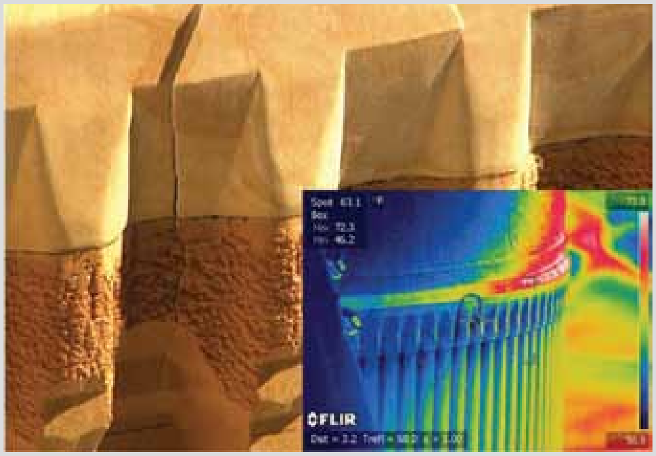
STS-133 External Tank Intertank Stringer Crack and Repair

Problem: Following the scrub for the initial launch attempt of STS-133, a crack was observed in the foam covering the intertank stringer near the intertank-to-liquid oxygen tank flange. Subsequent detailed examinations determined four stringers were cracked, which produced both ascent debris and structural (buckling) concerns. The investigation, led by the External Tank (ET) Project, determined the primary contributors were the use of a material susceptible to unstable crack growth due to anomalous thermal/mechanical processing, and high assembly stresses resulting from stringer fabrication and attachment characteristics.

NESC Contribution: The NESC augmented the ET Project Investigation Team with the addition of subject matter experts in the areas of mechanical loads, thermal and structural analysis, materials testing, nondestructive evaluation (NDE), statistical analysis, and human factors. In addition, the NESC team conducted independent structural failsafe and critical flaw size analyses, material thermal treatment sensitivity and mechanical strength studies, and statistical data analyses of material and subscale testing.

Result: The ET Project corrective actions were to repair cracked stringers with doubler plates, increase stringer capability with the installation of radius blocks, and conduct a tanking test followed with NDE to verify stringer integrity. The NESC provided an in-depth and independent examination of the ET Project plans and generated critical material property data for the understanding of the most probable origin of the thermal/mechanical processing anomalies.

Lessons Learned: The continued emphasis on maximizing shuttle payload resulted in the replacement of the intertank stringer material from moderate strength/high ductility to a high-strength/moderate-ductility alloy. This material substitution resulted in an approximate 50-pound weight reduction. However, the addition of the radius block modification negated the weight savings. The lesson learned was that a systems consideration should be taken with any material substitution to ensure that a potential weight reduction is not replaced with increased manufacturing problems and/or operational issues.



Visible-light and infrared (inset) photographs of ET foam crack.

In-Suit Light Exercise Prebreathe Protocol for Extravehicular Activities

Expedition 28 crewmember, Mike Fossum, in the ISS Quest airlock prior to an EVA during STS-135.

Problem: Astronauts performing extravehicular activities (EVAs) on the International Space Station (ISS) are exposed to risk of decompression sickness when transferring from the cabin atmosphere of 14.7 pounds per square inch (psi) to the suit operating pressure of 4.3 psi. This risk is mitigated by the use of oxygen prebreathe to wash out nitrogen from the astronaut's bloodstream, prior to each EVA. Since 2006, the primary prebreathe method used on ISS is the "campout" protocol, where the EVA astronauts campout the night before the EVA in the airlock at a reduced atmospheric pressure of 10.2 psi. This procedure reduces the in-suit prebreathe time on the day of the EVA, but isolates the crew in the airlock for over 8 hours. To provide an alternative protocol, JSC's Space and Life Sciences Directorate (SLSD) developed the in-suit light exercise (ISLE) prebreathe protocol. The ISLE prebreathe protocol includes a 50-minute period of light exercise in the spacesuit and has some operational benefits, including eliminating the overnight isolation in the airlock.

NESC Contribution: The NESC assisted the JSC SLSD in forming a peer review committee of experts in decompression sickness risk and the operational aspects of EVA to assess the proposed use of the ISLE prebreathe protocol. The peer reviewers looked at physiological data from ground trials of the prebreathe protocol, operations data including EVA prebreathe history, and the operational details of the planned ISLE implementation on ISS.

Result: The peer review committee found, based on all of the data reviewed, that the ISLE prebreathe protocol was acceptable for use on the ISS. The ISLE protocol was subsequently used during the third EVA performed during the STS-134 mission and during the STS-135 EVA. Both EVA crews endorsed the continued use of ISLE on ISS.

Orbital Sciences Corp.

Artist's rendition of a Taurus II on the launch pad at WFF.

Taurus II On-Pad Stage Testing Plan Study

The NESC, at the request of the NASA Commercial Cargo and Crew Program Office (CCCPO), evaluated the risks associated with conducting the new Orbital Sciences Corp. (OSC) Taurus II launch vehicle first-stage qualification test on the launch pad at WFF. The Taurus II system is to be used for International Space Station resupply. To evaluate the risks in conducting the stage qualification tests, the NESC extensively reviewed OSC stage qualification test plans and design analysis documents; performed computational fluid dynamic, acoustic, and thermal analyses; and obtained test data from Taurus II AJ-26 single rocket engine tests conducted at SSC. The NESC independent assessment team identified four potential hazards, including inadvertent launch, on-pad fire/explosion, damage to the pad infrastructure, and damage to the stage qualification test article. Each hazard was rated for likelihood and consequence. Recommendations for additional structural and thermal analyses of the test-unique stage/pad interface hardware were given to OSC, CCCPO, and WFF safety organizations.

Launch Pad Acoustic Suppression Ring Weld NDE

Nondestructive evaluation (NDE) of the welds on the launch mounts of the Taurus II launch pad at WFF was performed using ultrasonic testing (UT) instead of the specified radiographic (RT) method. This was done because of the difficulty of inspecting the thick sections of the mounts with RT. The NESC was asked to determine whether the UT provided an acceptable inspection. NDE Technical Discipline Team experts reviewed the NDE inspection reports and concluded that UT could be submitted as a waiver to the RT requirements. However, they noted numerous deficiencies in the UT inspection reports and recommended that an audit be performed or the welds be re-inspected. The project accepted the recommendation, and the structure was re-inspected by a different NDE contractor.

Space Operations

International Space Station Control Moment Gyro Assessment

Problem: The International Space Station (ISS) experienced a failure of control moment gyro (CMG-2) and an anomaly in CMG-3, which were both replaced and returned for examination. Analysis of the CMG issues is continuing.

NESC Contribution: Technical experts selected from the areas of materials; bearings; lubrication; and guidance, navigation, and control (GNC), who participated in the original assessments, continued to track recommendations made in those assessments. Previous assessments performed by the NESC on the CMG-1 failure and CMG-3 anomaly included support from the NESC Mechanical Systems and GNC Technical Discipline Teams (TDTs). When CMG-3 was disassembled upon return from the ISS, dewetting of the bearing surfaces was noted. While no such observation was made on the CMG-1 hardware, dewetting continues to remain on the fault tree as a possible contributor to the CMG-3 anomaly observed in flight, resulting in its shutdown and eventual return to Earth. In the course of addressing this possible contributor, a test was run using the CMG-3 flight bearings and flight-like electronics. Periodic inspection of the bearings was performed to note whether de-wetting was produced in the test. After a few months dewetting was noted on three balls in one of the bearings. Failure of the test occurred shortly thereafter, but the interpretation of the results was marred by the excessive concentration of contaminant introduced to produce the dewetting and the previous testing performed on the bearings used in the test, calling into question the validity of the results. The current NESC assessment focuses on evaluating the credibility of dewetting as a possible contributor to root cause.

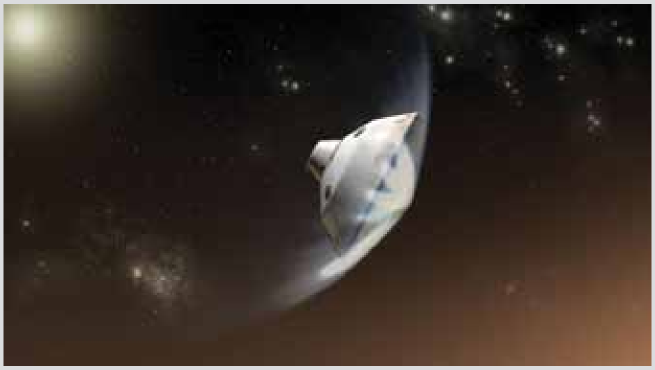
The CMG-3 was replaced during STS-118 mission to the ISS.

Result: Testing is planned to better understand the performance effects and associated risks, if any, of the wax contaminant known to be present in the four CMG assemblies currently in operation on the ISS.

Space Shuttle Orbiter L1L Thruster Investigation Support

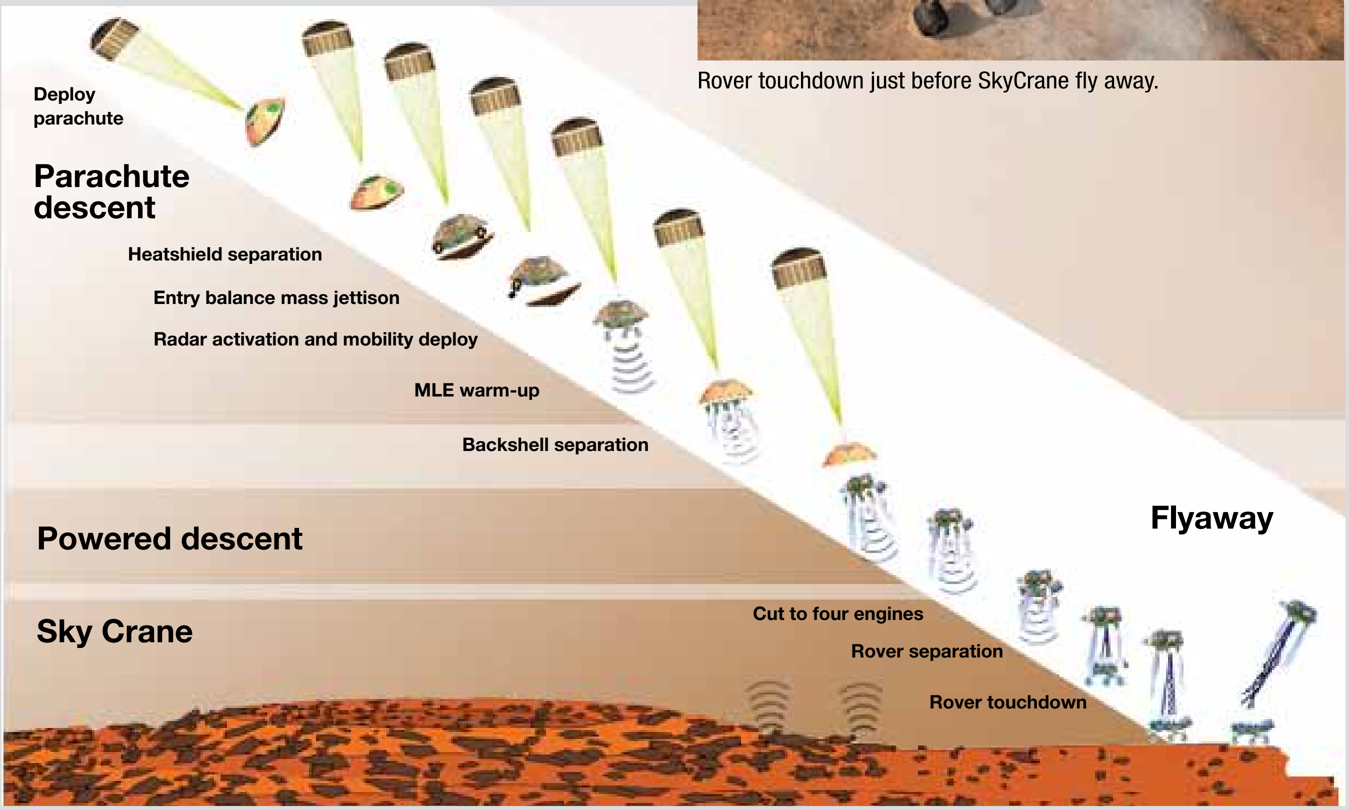
During developmental testing of a space shuttle orbiter's orbital maneuvering system/reaction control system, damage was sustained to the L1L thruster. The NESC was requested to provide an independent technical review of the failure assessment, fault tree structure, scenario generation, thermal and flow analyses, and flight rationale generation. The NESC team provided independent evaluations, which included thermal and one-dimensional draining model and Zot (oxidizer and/or fuel passages) analysis. The NESC team identified fault tree enhancements that described the proximate causes and provided qualitative and quantitative analysis predictions, which further substantiated the most probable scenario (i.e., leaking oxidizer valve and migration of oxidizer into the fuel passages/manifold leading to detonation and damage). The NESC team concurred with the proposed flight rationale that this type of failure could not occur during flight as the following conditions would not exist: a leaking oxidizer valve, horizontal orientation at 1g, and ambient temperatures. As a follow-on to the Orbiter Project investigation, the NESC conducted high-strain-rate tensile testing of nozzle material extracted from a thruster with similar exposure time to the unit involved in the incident. This testing revealed that the detonation was not the sole contributor to the brittle (cleavage) fracture observed in the test failure.

Orbital maneuvering system showing the L1L thruster (circled).



MSL entry into Mars atmosphere.

Rover touchdown just before SkyCrane fly away.



Mars Science Laboratory entry, descent, and landing sequence.

Simulation Framework for Rapid Entry, Descent, and Landing Analysis

Entry, descent, and landing (EDL) flight simulations are typically developed for specific tasks. In many cases, once the effort is completed, the simulation models are not adequately documented or retained. Many projects or studies requiring EDL would benefit from high-fidelity simulations with a library of validated and documented models. In this activity, the NESC team converted and archived a number of current and historic EDL models and scripts into a secure user library with appropriate user documentation and test cases. The team also developed several new models currently of interest in the EDL community. As a whole, the models included aero-dynamic and mass models of entry vehicles, atmospheric and gravity models of planets and moons, guidance and control algorithms, a multimode Kalman navigation filter for onboard state estimation, aero-dynamic uncertainties for dispersion analyses, guidance models for aerocapture and aerobraking, and several basic attitude-control models.

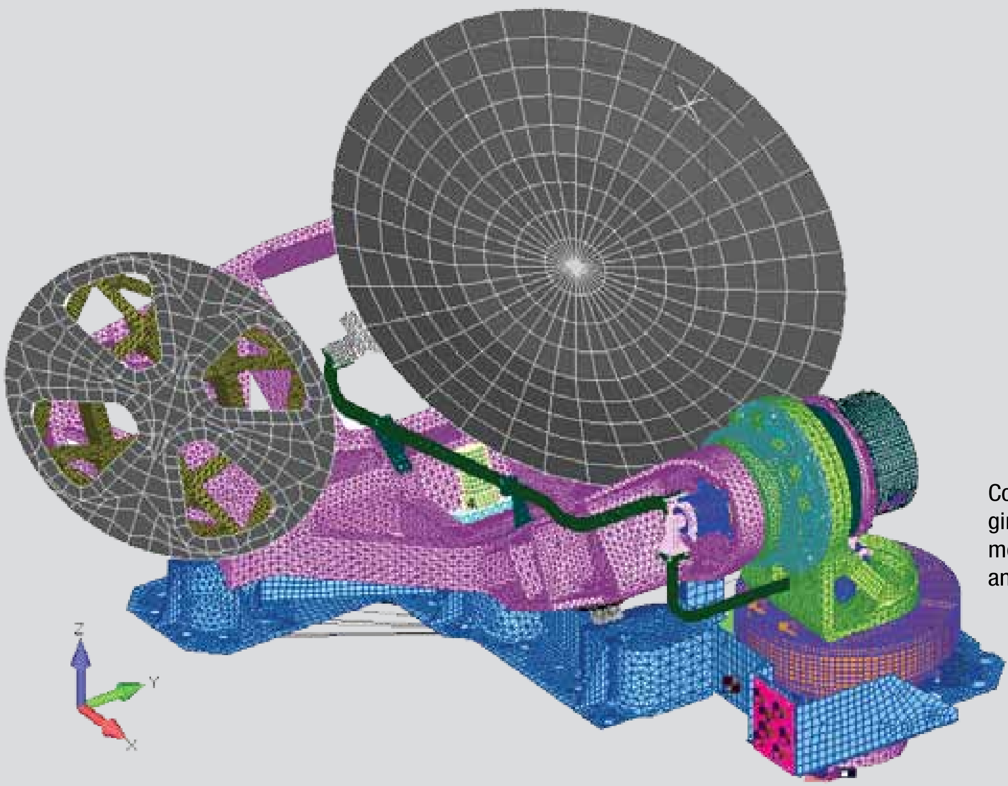
Products of this activity are expected to help define the required architectures and investment strategies to aid a wide range of future robotic and human exploration missions. Overall, having this EDL flight simulation capability readily available increases the ability of the Agency to evaluate a wide range of EDL systems and problems in systems analysis studies, preliminary design, mission development and execution, and time-critical assessments.

Science

CoNNeCT Spacewire High Data Rate Anomaly Investigation

Spacewire printed circuit board.

The GRC Communications, Navigation, and Networking Re-Configurable Testbed (CoNNeCT) Project experienced technical issues with two aspects of its spacewire implementation. The first issue occurred during the CoNNeCT functional testing and affected the cable; the second issue involved the implementation of the spacewire protocol. A request for NESC support to assist in identifying root cause and corrective action recommendations was successfully completed with the identification of the causes for both issues, respectively: (1) Cable harness manufacturing issues and (2) peripheral component interconnect (PCI) software driver incompatibility. The cable harness issue was resolved after a review of the manufacturing process and subsequent recommendation to perform a more thorough vacuum bake-out to remove residual alcohol used in the cleaning process as well as implementing larger cable bending radius routing to avoid internal cable compression. The protocol problem was resolved using a PCI mezzanine card (PMC) bus analyzer on loan from GSFC. With the PMC bus analyzer, GRC was able to identify the anomalous PCI transactions in the design associated with two READ direct memory access commands between the single board computer and the dynamics engineering spacewire board being processed at the same time, resulting in the observed lockup condition. Subsequent software updates were able to correct the conflict in order to proceed with remaining testing.



CoNNeCT antenna gimbal finite element model used in the analysis.

Independent Review of CoNNeCT Antenna Gimbal Structural Analysis

An independent review of the structural analysis and modeling of the antenna pointing subsystem integrated gimbal assembly (IGA) of the Communications, Navigation, and Networking Re-Configurable Testbed (CoNNeCT) was performed.

An NEI Nastran finite element model of the CoNNeCT antenna IGA was developed by Sierra Nevada Corp. (SNC). The NESC team peer reviewed this finite element model. The NESC raised issues regarding fastener modeling, baseplate boundary conditions, modeling related to gussets, and interfacing linear and quadratic elements. The responses to the issues raised by the NESC team were adequately addressed by SNC. The contractor has implemented the team's suggestions and corrected the identified model deficiencies. The model was revised, following most of the NESC suggestions except for one load case where a conservative approach was recommended. For this load case, the project decided that its approach was still low risk. The new margins of safety were evaluated and verified to be satisfactory except for this one load case.

Hubble Space Telescope Attitude Observer Anomaly Investigation

Problem: Recently the science operations of the Hubble Space Telescope (HST) have been compromised by an on-orbit anomaly called the attitude observer anomaly (AOA). The HST experienced occasional losses of lock during fine guidance sensor (FGS) guide star acquisitions, threatening a potential loss of science. These failures were associated with an increasing disparity between the FGS-derived estimates of gyro bias calculated in the day portion of the orbit and those calculated in the night portion.

An HST gyro showing the heaters (2 bands on left) and secondary temperature sensor (on right).

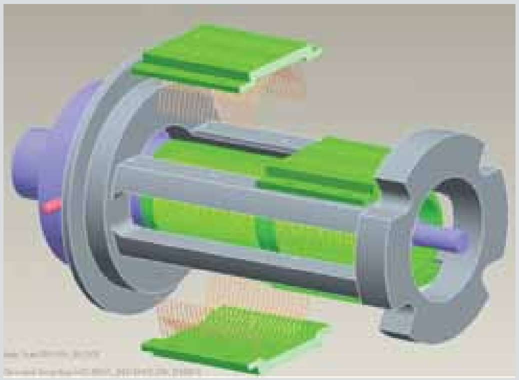
NESC Contribution: In February 2011 GSFC formed an Anomaly Review Board (ARB) to investigate this anomaly. Members of the NESC Guidance, Navigation, and Control Technical Discipline Team served as members of this board, contributing to the formulation of recommendations for resolving, or at least mitigating, the AOA phenomena. The NESC identified and provided HST gyro subject matter experts from outside NASA to support the ARB's deliberations. These were retired engineers from the gyro vendor who had unique hands-on knowledge regarding the HST gyro design, build, and test processes. Members of the NESC Engineering Statistics Team analyzed and evaluated HST telemetry data, looking for AOA indicators, trends, and patterns. The NESC also performed orbital analyses to identify the source of an unusual oscillation, with a 47-day period, that was superimposed on a secular increase in the AOA amplitude. The source of the oscillation was determined to be cross coupling into a failing gyro from a second otherwise healthy gyro that was exceptionally sensitive to the Earth's magnetic field.

Result: The ARB initially focused on the thermal control of six degrees of freedom floated rate-integrating gyros that function as the HST's primary pointing reference. The ARB found that the AOA was caused in part by the inability of the gyro's primary low-bandwidth heater controller to suppress the thermal "heat pulse" caused by main bus voltage transients, which typically occur at the spacecraft's eclipse exit (day) and entry (night). Upon the ARB's recommendation, all six HST gyros were switched in July 2011 to their secondary high-bandwidth heater controllers. Operating the gyros on the secondary heater controllers, which have a bandwidth 10 times higher than the primary heater controllers, reduces their thermal transients. Although the root cause mechanism had not been definitively identified by the ARB at that time, the reconfiguration to the secondary heater controllers proved to be an effective on-orbit mitigation of the AOA.

The ARB continued its investigation into the AOA root cause using a detailed fishbone analysis approach. The ARB subsequently linked the AOA to the corrosion of the multiple flex leads, each the diameter of a human hair, which serve as the internal electrical connection to the gyro float. Therefore, there is the potential for the AOA to occur in any HST gyro. The ARB concluded its work in September 2011 and has recommended that the HST Project minimize main bus voltage transients in order to limit gyro flex lead degradation and, by association, the AOA. This includes reducing occasional large load-shedding events, such as those which occur during spacecraft safing events, as well as minimizing the twice per orbit day/night power transients. As a longer term fix, the ARB recommended the addition of new open-loop AOA compensation in the HST's onboard attitude control flight software. The NESC is continuing to support the HST Project by updating gyro life predictions and by considering the development of a new multidisciplinary model of the gyro flex lead degradation physics.

Fermi On-Orbit Slip Ring Anomaly

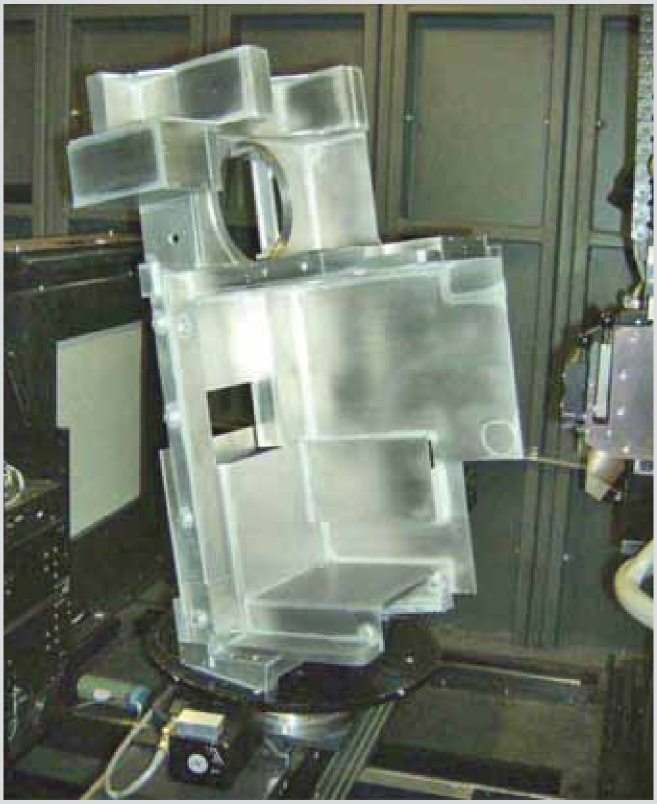
The NESC provided technical support for an investigation of a Fermi on-orbit coarse sun sensor (CSS) anomaly believed to have been caused by a solar array slip ring assembly (SRA) malfunction. The SRA was manufactured in Europe and sold as heritage equipment from the Swift spacecraft. From review of the on-orbit telemetry, the team methodically ruled out component anomalies other than the SRA. Minor operational changes to preserve slip ring life were recommended and implemented. To date, the anomalous behavior has stabilized and the spacecraft is fully functional.



An illustration of the Fermi slip ring design.

Assessment of the CrIS Instrument Structural Frame for JPSS

Problem: The Joint Polar Satellite System (JPSS) cross-track infrared sounder (CrIS) instrument utilizes an aluminum-beryllium-metal-162 (AlBeMet) structural frame to mount a precision interferometer and beryllium (Be) optical bench, as well as electronics, thermal control, and in-situ calibration components. Electron-beam (e-beam) welding was the baseline approach to join four AlBeMet parts into a single frame. After a successful study using welded AlBeMet test coupons, e-beam welding runs were conducted using full-sized aluminum (Al) frame mockups with AlBeMet weld interfaces. Initially, AlBeMet weld joints were performed on four mockups and inspected for defects using x-ray computed tomography imaging. Inspections revealed unacceptable weld penetration, porosity, and cracks. Improvements to weld parameters and fixture restraints yielded acceptable weld penetration and porosity in four additional weld mockups; however, cracks persisted in certain weld areas.

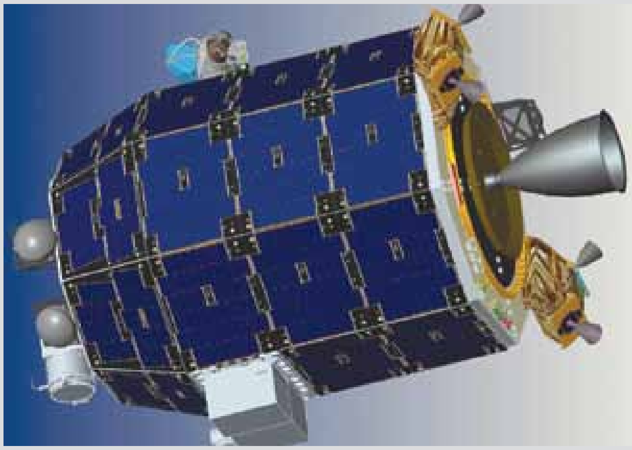

CrIS frame during x-ray computed tomography inspection.

NESC Contribution: The NESC was requested to assess the baseline e-beam welding process to determine if a flightworthy welded frame was achievable for JPSS-1 and provide recommendations on alternative frame materials and manufacturing processes to mitigate CrIS development risks. The NESC reviewed documents from prior CrIS frame design, manufacturing readiness, and test reviews; conducted a technical interface meeting on the baseline welded AlBeMet frame with the CrIS Project; and reviewed a trade study by the CrIS contractor on 12 alternative frame materials and construction options. The NESC provided preliminary and final risk assessments, findings, observations, and recommendations to the CrIS Project.

Result: Scanning electron microscope investigation of crack samples taken by the CrIS contractor revealed liquation cracking in partially melted zones of Be and liquid Al during AlBeMet welding as the defect cause. Further weld improvements are needed to control liquation cracking in welded AlBeMet. Two alternative approaches for the CrIS frame were recommended by the NESC to provide JPSS-1 risk mitigation. The primary alternative is a one-piece frame machined from a single AlBeMet billet, which is a larger AlBeMet structure than previously machined and requires improved billet screening and machining controls. A backup alternative is a one-piece frame machined from a single Al billet; but the Al frame option exhibited a dynamic interaction at 144 Hz (five times higher vibration levels at the interferometer than the AlBeMet frame), which requires design improvements to alleviate. The CrIS Project decided to proceed with the single-piece AlBeMet frame.

Lunar Atmosphere and Dust Environment Explorer GNC Parameter Support

Due to the high thrust-to-mass ratio of the main engine to the mass of the spacecraft for the Lunar Atmosphere and Dust Environment Explorer (LADEE), many of the guidance, navigation, and control (GNC) parameters associated with the thrust vector alignment and center-of-gravity tolerance and control are much tighter than typical spacecraft. Although achievable, these tighter tolerances do require special dynamic spin balancing and special attention to analyses and integration processes to meet these requirements. The NESC is currently providing technical support to the LADEE Project Alignment Working Group, and will provide guidance and monitor the activities associated with achieving these GNC-related requirements, to help ensure mission success. The LADEE spacecraft integration activities will start in the winter of 2011 and continue into 2012. LADEE is scheduled to launch in 2013.


An illustration of the LADEE spacecraft.

The Black Brant sounding rocket motor (black upper stage), operational since the 1960s, is the workhorse of NASA's Sounding Rocket Program.

Design Concept for New Sounding Rocket Sustainer Motor

Problem: NASA's Sounding Rocket Program (SRP) provides low-cost opportunities to conduct leading edge research into many areas of interest, throughout and above the Earth's atmosphere. The SRP workhorse motor, used alone or as part of a multistage rocket, is a 1960s design manufactured in Canada. This motor has a long history of reliable performance, but over the last several years, its reliability has decreased significantly for various reasons. A new design that takes advantage of modern design and production practices is needed to ensure the reliability of sounding rocket missions.

NESC Contribution: The NESC is developing a conceptual design of a new sounding rocket motor that meets the performance and cost requirements of the SRP. The design team consists of members from WFF, NESC, KSC, and MSFC. Additionally, propellant characterization testing is being done in partnership with the U.S. Army, and opportunities for motor casting and testing are being pursued with the U.S. Navy. The goal is to generate a government-owned design that will be produced in economical lots by private industry.

Result: The design team has generated a conceptual design that meets the performance requirements and ease-of-manufacture goals. All design and manufacturing parameters are well within current capabilities and common practice. Cost estimates are being generated for the next phase of the development effort, which calls for three ground tests and three flight tests, as well as for the production motors. Sponsorship is being solicited for the next phase of the motor development.

Analysis of Flight Vibration and Shock Environments for Black Brant X Upper Stage

The NESC investigated the flight vibration and shock environments for two recent sounding rocket launches. Accelerometer data from the flights were analyzed and informal reports provided to the NASA sounding rocket operations contract at WFF. Each vehicle had a Terrier first stage and a Black Brant second stage. The Black Brant motor was found to have a motor pressure oscillation at 110 Hz, with integer multiples thereof. This effect is apparent toward the end of the Black Brant burn from 35 to 45 seconds. The oscillations did not setup in a pure sinusoidal or sinusoidal sweep pattern, but were rather found to have a narrowband characteristic.

The NESC also analyzed a shock event at ~0.15 seconds from a total of six flights. The shock is most likely due to a "jointslip" effect between the connected modules. This effect is a variant of "stickslip," in which the static friction is higher than kinetic friction. The slip is driven by rigid-body acceleration, as Terrier-Black Brant vehicles-typically accelerate from zero to 7g from zero to 0.15 seconds and the rigid-body acceleration compresses the vehicle. The average jerk is very high at 47g/sec. Thus there is a rapid accumulation of strain energy in the vehicle and its joints. The shock pulses represent the release of this strain energy as the vehicle tries to settle into a new equilibrium condition.

Science

Pyrovalve Booster Interface Temperature Measurement

Problem: The Mars Science Laboratory (MSL) Project is using pyrovalves with stainless steel primer chamber assemblies with a "V" channel shape (V-PCA) rather than the heritage aluminum design with a "Y" channel shape (Y-PCA). The design was changed to reduce flame channel melting/erosion, eliminate potential obstructions at the channel intersection, and reduce variability. MSL qualification testing of the V-PCA design demonstrated faster booster ignition and little or no melting/erosion. However, further testing was needed to quantitatively compare the two designs.

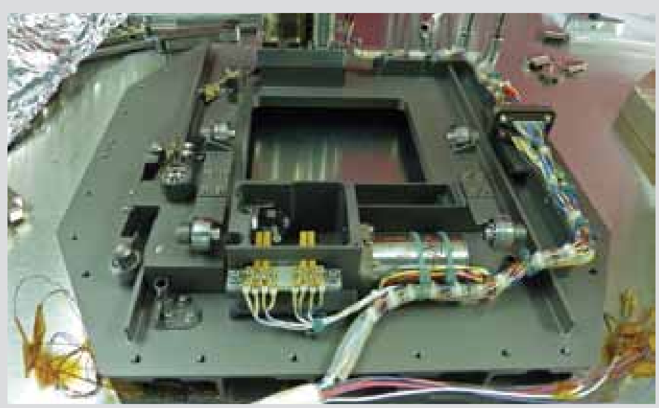
NESC Contribution: The WSTF developed a specialized method to compare the two PCAs. The method used high-speed infrared pyrometers (6μs response) and video cameras (20,000 frames per second) to observe the underside of the booster cover (propellant interface) through a sapphire window. Other tests also evaluated the effects of larger diameter flow channels and varying skews between the firing of the redundant initiator firings.

Result: The new PCA design delivered an average propellant interface peak temperature of 315C (600F) higher than the aluminum design in about one-half the time and produced pressures that were several thousand psi greater. However, dual simultaneous firings of both PCA types reduced the maximum temperature several hundred degrees below the threshold needed to ignite the booster. This potential failure mode occurred even with flow paths with four times the original cross-sectional area. These data will help future NASA projects to properly evaluate the selection and use of PCAs.

Benjamin Gonzalez, Jacobs Scientist (seated) shows close-ups of post-firing PCAs to project leader, Steve McDougle (left), and assessment lead, Regor Saulsberry.

James Webb Space Telescope NIRSpec Microshutter Subsystem Investigation

The NESC is providing an independent assessment of the James Webb Space Telescope (JWST) near infrared spectography (NIRSpec) microshutter subsystem life test results. Although the mechanisms' performance met the two times life requirement, debris noted during post-test inspection is a concern for instrument operation. The NESC team, consisting of KSC, GRC, MSFC, ARC, GSFC, JSC personnel, and contractors, is evaluating the effect of contamination on the instrument's performance as well as conducting a series of tests to determine when, in the life of the unit, debris generation begins. In addition, the team will recommend a modification to reduce the amount of contamination, which will be based on engineering test data. The evaluation and recommendations are expected to be complete by the end of 2011.



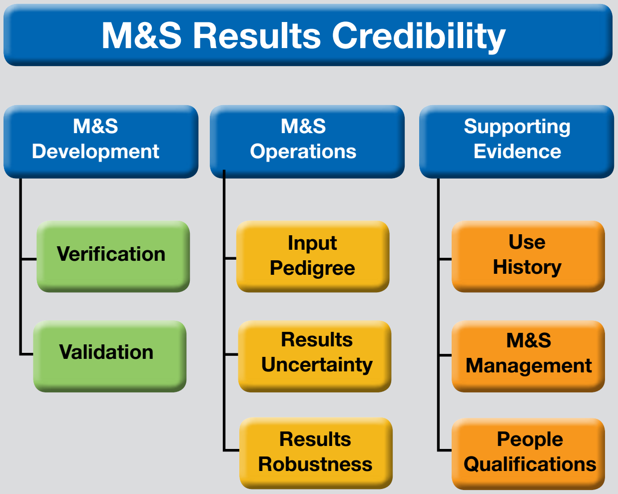
NIRSpec microshutter subsystem life test unit.

NASA Models and Simulations Handbook Development

Problem: The NASA Standard for Models and Simulations (NASA-STD-7009), developed in response to the Columbia Accident Investigation Board recommendations and approved in July 2008, is still not widely implemented or well understood within the Agency. Reasons for its slow adoption include its broad applicability across modeling and simulation (M&S) domains (i.e., it is not specific to any particular M&S application area or type), some of its terminology and intentions are not ubiquitously understood, and reticence to accept additional requirements that could add workload and/or cost to a project.

Inconsistent understanding of M&S risk and credibility assessment approaches also exists throughout the Agency. M&S risk assessments are used to determine which models and simulations influence critical decisions. M&S credibility assessments are used to communicate the credibility of M&S analysis results based on factors such as verification, validation, input pedigree, results uncertainty quantification, results robustness, use history, M&S management, and people qualifications.

NESC Contribution: The NESC team, consisting of M&S practitioners from nine NASA Centers, developed a handbook that includes a checklist with explanations, definitions, and examples, enabling programs and projects to more effectively implement the requirements and meet the fundamental intent of NASA-STD-7009. The primary goals of the M&S standard and handbook are to provide consistent M&S reporting, terminology, and risk assessment approaches and to ensure the credibility of M&S analysis results is properly conveyed to those making critical decisions. The team also worked with early adopters of NASA-STD-7009 to clarify requirements and document recommended practices.

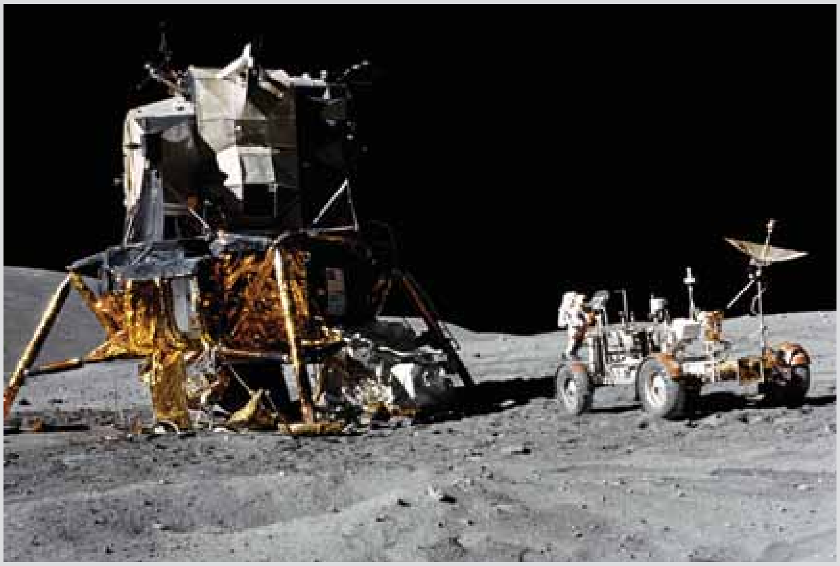


Factors in a credibility assessment of M&S analysis results.

Result: A growing community of M&S practitioners is using NASA-STD-7009 to guide the implementation of their projects and assess the adequacy of their products. Two early adopters are the Orion Multi-Purpose Crew Vehicle Program and the Human Research Program. The Commercial Crew Program has also included specific requirements to perform risk and credibility assessments for any critical M&S. The availability of a draft handbook was invaluable to increasing the use and understanding of NASA-STD-7009. The personnel benefiting from the handbook include M&S tool developers and operators, systems analysts, decision makers using M&S analysis results, and independent reviewers of M&S products.

The effort has also reinforced the need for technical discipline-specific guidelines to assist in implementation of the concepts of this standard within specific types of M&S. Specific examples, explanations, and recommended practices are crucial to understanding the requirements and intent of NASA-STD-7009.

Support to Google Lunar X-Prize for Apollo Landing Site Preservation Recommendations



Apollo 16 landing site showing lunar module and lunar rover.

Future spacecraft, such as those participating in the Google Lunar X-Prize, may be landing near and visiting historic lunar locations such as the Apollo Program landing sites. The NESC provided support in creating guidelines for protecting these sites from damage caused by either landing close to them or by making contact with or contaminating the artifacts located therein. In addition, future missions may provide the opportunity to observe any effects on the materials and hardware left on the surface of the Moon. These items have endured 4 decades of solar radiation, micrometeoroids, +250 F to -300 F temperature extremes, and lunar dust. The NESC team provided specific suggestions concerning how to use artifacts from these sites as engineering witness plates to understand long-term exposure to the lunar environment.

General

Doppler Radar Wind Profiler for Determination of Launch Winds

Problem: Atmospheric winds are a major factor that must be addressed during launch vehicle design and day-of-flight launch operations to maximize flight performance and minimize structural loads. Current launch site wind databases from balloon measurements are limited in size and temporal sampling intervals, leading to uncertainty in potential wind changes and vehicle loading.

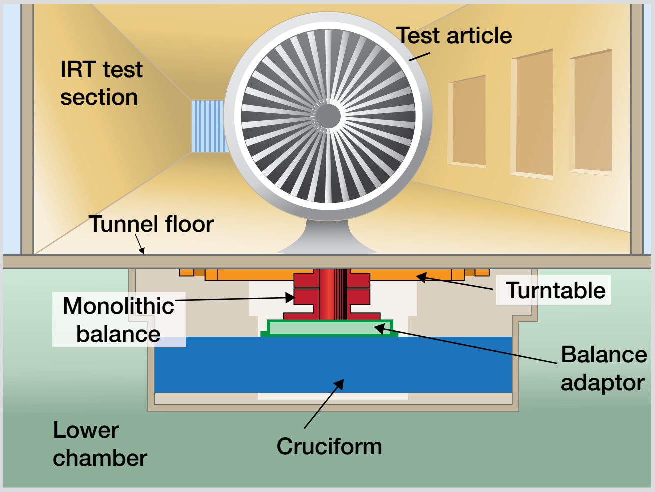
NESC Contribution: An NESC team began the development of an alternate database from 10 years of wind measurements made by vertically pointing Doppler radar wind profiler systems at KSC. This alternate database will provide much higher fidelity in sample size and temporal wind change, resulting in more accurate quantification of wind effects on vehicle loads and the potential for significant improvements in performance and reduced risk for future launch vehicles. After the NESC team began the development, the Space Launch System (SLS) Program decided to continue the work to quickly integrate the results into their launch vehicle development effort.

Result: Planned for completion in 2013, the database will be made available to NASA and commercial launch vehicle communities. In addition to the database, the SLS Program will pursue the development of algorithms to process Doppler radar measurements to be used for day-of-flight analyses and launch decisions. These algorithms would provide much more timely characterization of winds as compared to balloon measurements (15 minutes vs. 2 hours), resulting in more accurate determination of ascent loading, improved launch opportunities, and reduced risk.

Wind shear between 500-1000 feet, viewable by exhaust plume from STS-119 launch on March 15, 2009.

Icing Research Tunnel Force Measurement System Evaluation

Problem: GRC's Icing Research Tunnel (IRT) is one of NASA's unique aerodynamic test facilities. It is one of the largest icing wind tunnels in the world and is constantly in high demand due to this unique capability. One of the tunnel's main features is a large external balance and turntable system. The tunnel needs to update this force measurement system (FMS) to increase the force and moment measurement accuracy and to improve facility throughput. This FMS was designed and built in the early 1980s by civil servants who have since retired and GRC no longer has in-house knowledge of how best to upgrade the system. The NESC was requested to assess the current system, develop new concepts if required, and develop cost estimates and specifications for any suggested upgrades.



NESC recommended concept for GRC IRT FMS includes a new monolithic balance and balance adaptor and modifications to the existing turntable and cruciform.

NESC Contribution: The NESC created a team of experts from NASA Centers and industry to address this issue. Initially, a study was performed to gather data on the existing IRT-FMS. The team then conducted multiple technical interchange meetings on-site with IRT facility personnel. From these meetings, a better understanding of how the facility is currently used, how the associated calibration hardware is used, and clearer understanding of requirements were developed.

Result: The NESC team developed multiple configurations that would result in satisfaction of the requirements. These concepts were drafted, and pros and cons of each system were discussed with the facility personnel. The concept pictured is the recommended system that best meets all of the facility requirements. In the near future, estimates of various stages of facility upgrades will be made to allow the facility to perform improvements as funding becomes available.

Launch Vehicle Shell Buckling Knockdown Factors Testing

Problem: Refined knockdown factors may enable significant weight savings in launch vehicles and help mitigate their development and performance risks. The NESC Shell Buckling Knockdown Factor (SBKF) Project was established in March 2007 to develop and validate new analysis-based shell buckling design factors for future metallic and composite launch vehicle structures.

NESC Contribution: The NESC has supported a significant portion of the SBKF Project, including funding for the design and fabrication of large-scale test capabilities, fabrication and testing of five large-scale test articles, programmatic and technical support, peer reviews, and advocacy.

Result: In 2011, the SBKF Project made significant progress in several key work areas, including high-fidelity analyses and testing of metallic and composite structures, benchmarking of commercial codes for nonlinear structural analysis, developing the first generation analysis-based shell buckling design factors, and a draft of the new design guidelines for buckling-critical launch vehicle shell structures. Some of the highlights include successful fabrication and testing of the first of two 27.5-foot-diameter orthogrid-stiffened barrels at MSFC in March 2011. The objective of these tests is to prove that the design data and methods that are being developed and validated for smaller scale barrels can be scaled to larger-diameter barrels such as those that would exist in the next generation of launch vehicles. The test articles were fabricated from excess space shuttle external tank barrel panels and were welded together using MSFC's new vertical weld tool. The test articles are instrumented with over 800 individual strain and displacement sensors. Low-speed and high-speed video image correlation systems were used to obtain full-field displacement and strain measurements during the pre-buckling, transient-buckling, and post-buckling test phases. The high-fidelity analysis predictions of the first full-scale test continue to correlate well. A second 27.5-foot-diameter test article is planned for testing in fiscal year (FY)12 and will be subjected to different loading conditions from the first test and will provide additional data for model validation. Once these analyses are validated at the subscale and full-scale levels, they will become the basis of refined analysis-based design factors.

In addition to the SBKF Project development efforts on aluminum-lithium (Al-Li) stiffened cylinders, this activity is pursuing a parallel effort for fiber-reinforced composite cylinders. The central goal of this composites effort is to examine how the refined buckling recommendations can be extended to composite cylinders. Experimental and analytical studies are underway to meet this goal. Industry partners are providing 8-foot-diameter and 13-foot-diameter composite cylinders for buckling tests. The 8-foot-diameter cylinder has an out-of-autoclave sandwich composite construction, and the 13-foot-diameter cylinder has an autoclave-cured, fluted core composite (FCC) construction with lightweight longitudinal joints. SBKF has completed a series of tests on the FCC subcomponents with and without low-speed impact damage and has also helped develop and validate a novel lightweight joint design. A 13-foot-diameter barrel has been successfully manufactured and was shipped to LaRC in August 2011. It is scheduled for testing in FY12. Preliminary screening tests were completed for an alternate thick-plate Al-Li alloy 2050 for heavy-lift core stage components, and the activity spun off into a small business innovation research effort. Preliminary results indicate that the 2050 material may provide significant weight savings in highly loaded, buckling-critical structures where tall stiffener cross-sections are desirable. Currently, Al-Li alloy 2195 is limited to a 2.0-inch thick plate. In contrast, 2050 can be made in a plate up to 6 inches thick and enables higher structural efficiency by using taller integrally machined stiffener sections. The SBKF Project sponsored the Third Annual Users Workshop with industry and NASA engineers and discipline experts in August 2011. Of the 40 plus attendees, 25 were from industry including representatives from Alliant Techsystems Inc., The Boeing Company, Lockheed Martin Corp., Northrop-Grumman Corp., United Launch Alliance, Limited Liability Corp., and Dynetics Inc. The workshop was a great success, highlighted by open discussion, feedback, and interest from industry attendees.

A section of a space shuttle external tank covered in photogrammetry targets shown mounted in the shell buckling test fixture.

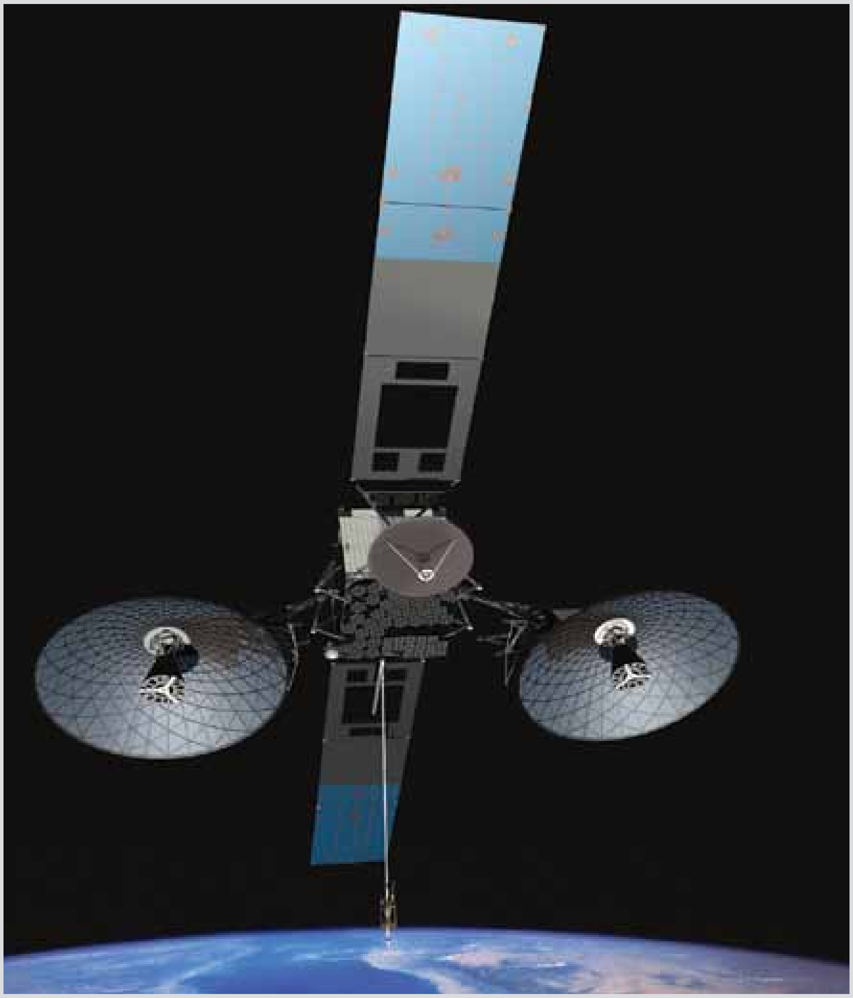
General

Reaction Wheel Assembly Lubricant Contamination Study

Problem: Grease contamination identified in bearings installed in 145 reaction wheel assemblies (RWAs) presented risks to flight for several NASA programs, including the Landsat Data Continuity Mission, Nuclear Spectroscopic Telescope Array, Tracking and Data Relay Satellite (TDRS) Spacecraft (K and L), and Soil Moisture Active Passive Mission.

NESC Contribution: In response to this issue, an NESC team was formed to identify affected programs and to evaluate root cause and the risks associated with the various actions considered at that time, including fly-as-is, clean and relubricate, and procuring bearings anew. The team was composed of experts from the NESC Mechanical Systems and Guidance, Navigation, and Control (GNC) Technical Discipline Teams representing the areas of bearings, lubrication, GNC, and mechanical systems. Working closely with the RWA and grease manufacturers, the NESC team was granted access to the respective facilities, proprietary drawings, processes, and procedures facilitating an expeditious review and risk assessment of the proposals under consideration.

Result: Overall, the team affirmed the root cause of the grease contamination and concluded that the cleaning and relubrication of affected RWA bearings presented no greater risk than flying new bearings.



TDRS K/L satellites contain RWAs identified in this study.

Flight Simulation Software Model Exchange Standard

Flight simulations in the American aerospace industry and NASA, in general, utilize independently developed software frameworks tailored for a single facility, and are thus incompatible with other facilities, even within the same NASA Center. Sharing of simulation models frequently requires extensive manual effort re-writing source code to “re-host” a model in a new environment. A multi-Center team was formed to assess a new method to make models more easily interchangeable. The team examined a draft American Institute of Aeronautics and Astronautics (AIAA) standard (now published as American National Standards Institute/AIAA-S-119-2011) that addresses this problem by using a specialized extensible markup language (XML) grammar to encode high-fidelity flight simulation models. Each participating Center developed the tools to automatically import and validate these XML models in their simulation framework and provided feedback to improve the standard and application in NASA facilities. Each Center was successful in importing and re-hosting an example aerodynamic model of a lifting-body re-entry vehicle into their real-time simulation framework. With these simulation exchange tools in place, each participating Center can re-host new models in minutes instead of months. Several suggestions for improvements in the standard were forwarded to the Modeling and Simulation Technical Committee of the AIAA and were incorporated in the released standard. Based on the NESC recommendation, NASA has adopted AIAA-S-119 as an endorsed NASA standard.

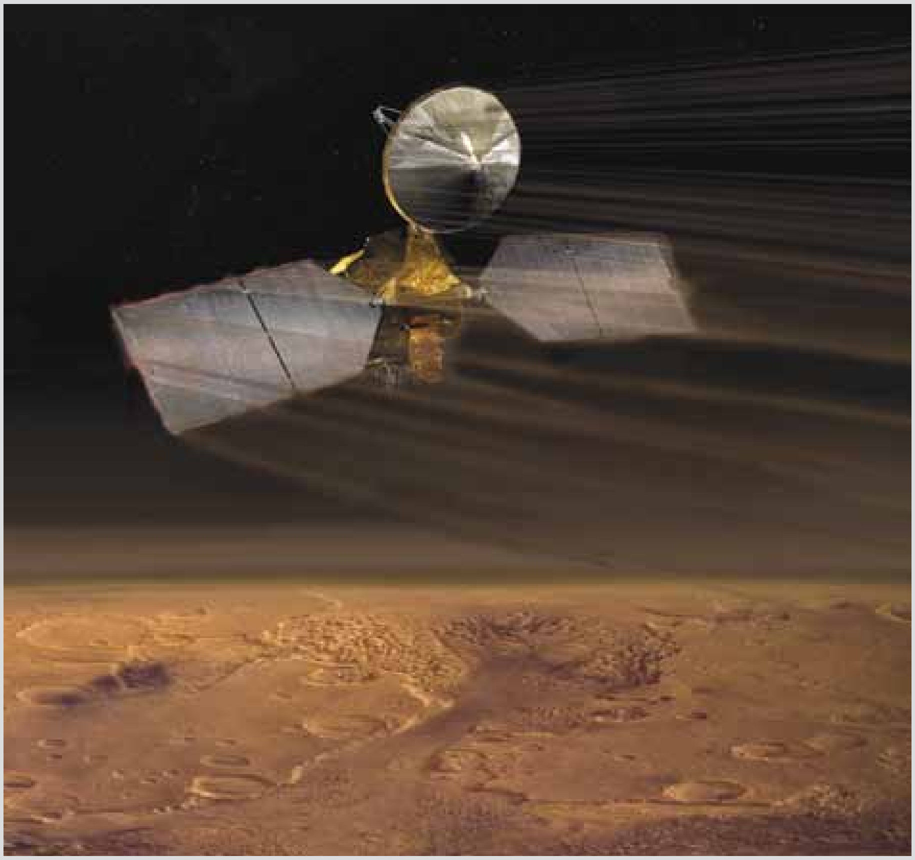
Vehicle used to test flight simulation model exchange standard.

NASA Continues Effort to Expand Data Mining and Trending

The NESC is leading an Agency-level Data Mining and Trending Working Group (DMTWG) whose purpose is to assist in the formulation and implementation of capability to strengthen trending of technical data in NASA programs and projects and to ensure appropriate visibility of data mining and trending. Through workshops, monthly meetings, training, and supporting algorithm development, the NESC has developed working relationships with data mining and statistical experts within NASA, other government agencies, academia, and industry. The DMTWG is assisting NASA organizations by providing data mining expertise to relevant NESC assessments. The team also sponsors interns and student faculty teams to assist in data mining activities. This working group provides a forum to enhance data mining and trending communications across the Agency by sharing ideas, methods, technologies, processes, tools, and lessons learned.

Development of an Autonomous Aerobraking Capability

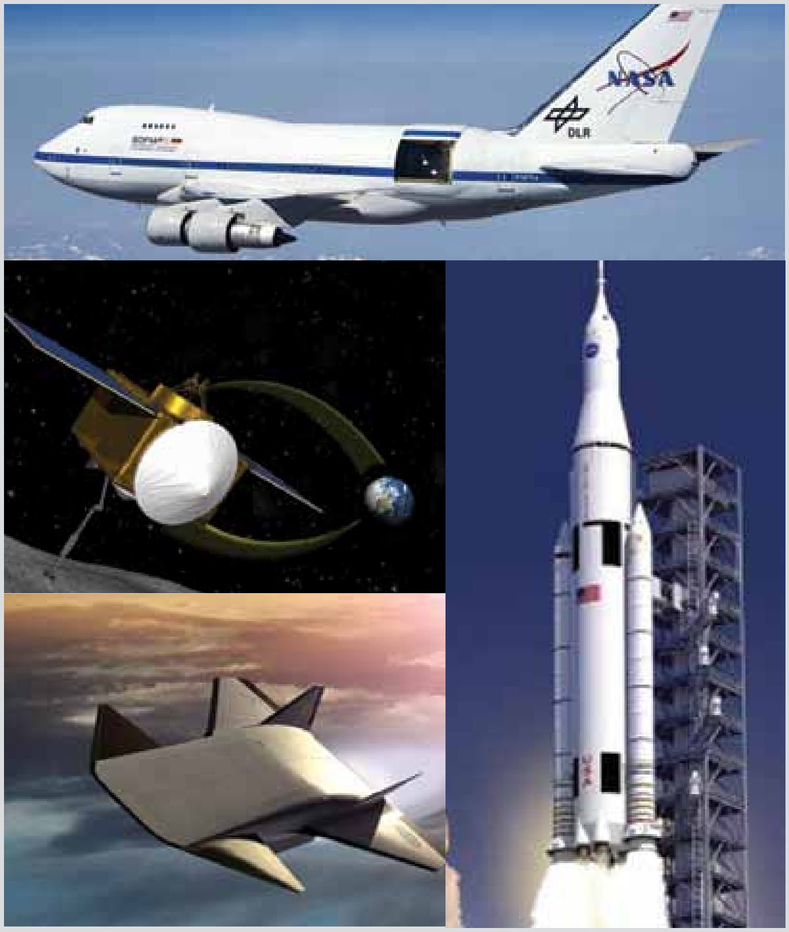
Problem: NASA uses aerobraking to reduce the fuel required to deliver a spacecraft into its desired final orbit around a target planet or moon with a significant atmosphere. While aerobraking reduces the propellant required to reach the final orbit, this reduction comes at the expense of orbital insertion time (typically 3 to 6 months) and continuous deep space network (DSN) coverage, and requires a large ground staff to continuously monitor the spacecraft during the aerobraking maneuver. The requirement for ground monitoring and trajectory correction introduces the potential for error due to time lag between Earth and the spacecraft, and the possibility that the critical data entry could occur during nontraditional working hours. This potential for error increases during the final orbital insertion phases, as the requirements and frequency for trajectory corrections increase and the ability to correct prior errors decreases. Studies indicate much of the daily operations during aerobraking could be moved to the spacecraft (autonomous aerobraking), thus reducing risk and saving much of the cost required for the aerobraking phase.



The Mars Reconnaissance Orbiter dips into the thin Martian atmosphere to adjust its orbit in this artist's concept illustration.

NESC Contribution: An NESC team is developing the capability to move the ground-based daily aerobraking maneuver processes onboard the spacecraft. These onboard processes include an ephemeris (orbital position) estimator, atmospheric density modeling, thermal modeling of the critical spacecraft elements, and maneuver strategy logic to keep the spacecraft safe and provide for the proper final orbital insertion. This suite of models and algorithms is known as the autonomous aerobraking development software (AADS). Mars, Venus, and Titan are the most likely targets that would use aerobraking, and each has significantly different aerobraking challenges.

Result: Preliminary testing of the initial AADS at Mars and Venus with ground-based "truth" simulations indicates that AADS could allow for autonomous control of a spacecraft for approximately 7 days with sufficient margin to account for uplink and other delays before a ground-based update would be necessary. This 7-day update cycle meets the goal set for AADS and could greatly reduce the DSN and ground-staffing requirements. Ultimately, AADS will be targeted for inclusion on a future spacecraft mission for flight evaluation in a "shadow mode," where onboard autonomous aerobraking commands would be compared to the actual aerobraking commands implemented by the ground operations team. Once shadow-mode flight validation is successfully completed, autonomous aerobraking could be used as the prime aerobraking operations strategy for future missions.



FM systems play a prominent role within NASA's aeronautics, human, and robotic spaceflight missions.

Development of a Fault Management Practitioner's Handbook

Problem: Over the last several decades, NASA engineers have established a number of techniques, methods, and approaches for designing, implementing, and testing fault management (FM) systems for spacecraft, launch vehicles, aeronautical vehicles, and ground systems. One can define FM to include fault tolerance, fault mitigation, and fault protection. FM is a nontraditional discipline, as compared to the structures discipline, most often affiliated with systems engineering and/or software engineering. Generically speaking, FM encompasses functions that enable an operational system to prevent or detect, isolate, diagnose, and respond to anomalous and failed conditions interfering with nominal mission operations. FM is beginning to be recognized as an engineering discipline that addresses the occurrence of faults in a given system. It serves to provide a reliable means for reducing the impact of faults through cooperative design between system-level and subsystem-level elements.

The performance of NASA's FM systems has generally been successful. However, in several cases, development of these systems has adversely stressed NASA's programmatic and engineering resources. In particular, flight projects have suffered from unexpected cost growth and schedule slips during final FM system integration and test. It has become apparent that reliable and affordable FM systems are not constrained by technology, but rather by a lack of systematic engineering and programmatic discipline.

NESC Contribution: The NESC recognizes that FM is a key driver to increase safety, reliability, availability, and performance in NASA's systems, and should have the rigor of other safety critical processes. To provide some of that missing rigor, the NESC, in collaboration with JPL, has developed a NASA Fault Management Handbook, NASA-HDBK-1002, to provide overarching conceptual engineering guidelines and recommended best practices.

Result: The handbook has been entered into the formal NASA Standards Program Office system, and it recently completed a comprehensive Agency-level review and comment cycle. FM is overdue to move from an art to an engineering discipline characterized by a known, agreed upon, and consistent methodology to structure FM and its relationship to other branches of engineering and design. The insights and concepts captured in this handbook provide a basis for moving the field toward a formal and consistent methodology. Application on future programs may help to avoid program cost overruns, schedule slips, and in-flight failures traceable to a lack of established approaches as well as disciplined and systematic FM development techniques. The NESC will continue to work on maturing the handbook with plans for disseminating it to Agency users in 2012.

Innovative Techniques

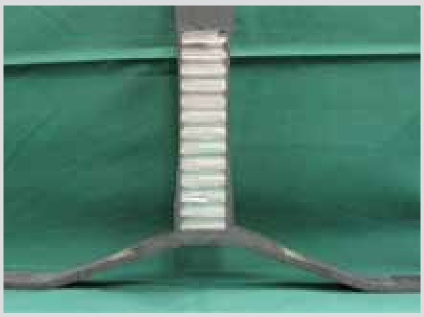
Innovative approaches and techniques developed from NESC assessments

The composite crew module underwent destructive testing in LaRC's Combined Loads Testing Facility

The NESC Composite Crew Module (CCM) Project was a rapid design and development project conducted from 2007 to 2010. The final product was a full-scale CCM designed, manufactured, and tested, ultimately to destruction, by a NASA and industry team that achieved the early design mass predictions and the pre-test analytical performance predictions. The 3-year project incorporated a number of technology spin-offs that are directly relevant to future composite structures. There are six engineering reports describing aspects of CCM as well as conclusions from the overall effort. These reports include Design, Analysis, Materials and Processes, Manufacturing, Test, and Nondestructive Evaluation. Each of these reports provides detailed discussions of the unique technology applications and are available on **nesc.nasa.gov.**

CCM Material and Processes Report

NASA/TM-2011-217189



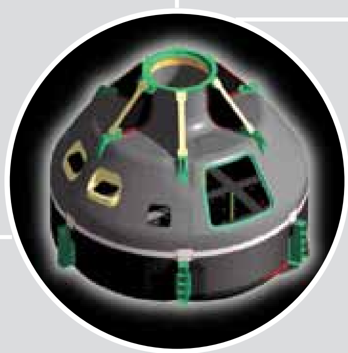
Co-cured 3D woven joints

Damage tolerance assessment

CCM Manufacturing Report

NASA/TM-2011-217187

Out of autoclave, Kapton heater localize material curing and repair system



CCM Nondestructive Evaluation Report

NASA/TM-2011-217191

Infrared thermography inspection

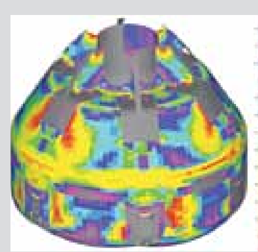
CCM Test Report

NASA/TM-2011-217190

Fiber optic strain measurement system

CCM Analysis Report

NASA/TM-2011-217188



Application of hypersizer software code

Flying Through Periods of Instability

In 2010 the NESC performed an assessment of the destabilizing impact of the former Orion Crew Exploration Vehicle (CEV) service module propellant slosh dynamics on the Ares-I crew launch vehicle flight control system (FCS). Concerns had been raised about the Ares-I boost phase stability and control because the standard frequency domain synthesis methods could not yield an FCS design with sufficient gain and phase stability robustness margins which also met the performance requirements. The assessment prompted a follow-up investigation into how NASA and industry have historically addressed regions of instability or violations of margin requirements. When stability robustness margin requirements cannot be satisfied using frequency-domain methods, alternative methods are then needed to ensure that deficient stability margins do not present a high risk of a flight control issue (e.g., loss of control) during the mission. A large body of experience has been accumulated at NASA regarding successfully flying through temporary periods of linear instability as the flight environment and vehicle dynamics undergo rapid changes. For example, the space shuttle had ascent and entry guidance, navigation, and control (GNC) stability verification issues. The Space Shuttle GNC Team identified four possible techniques for accomplishing entry FCS certification with deficient stability margins:

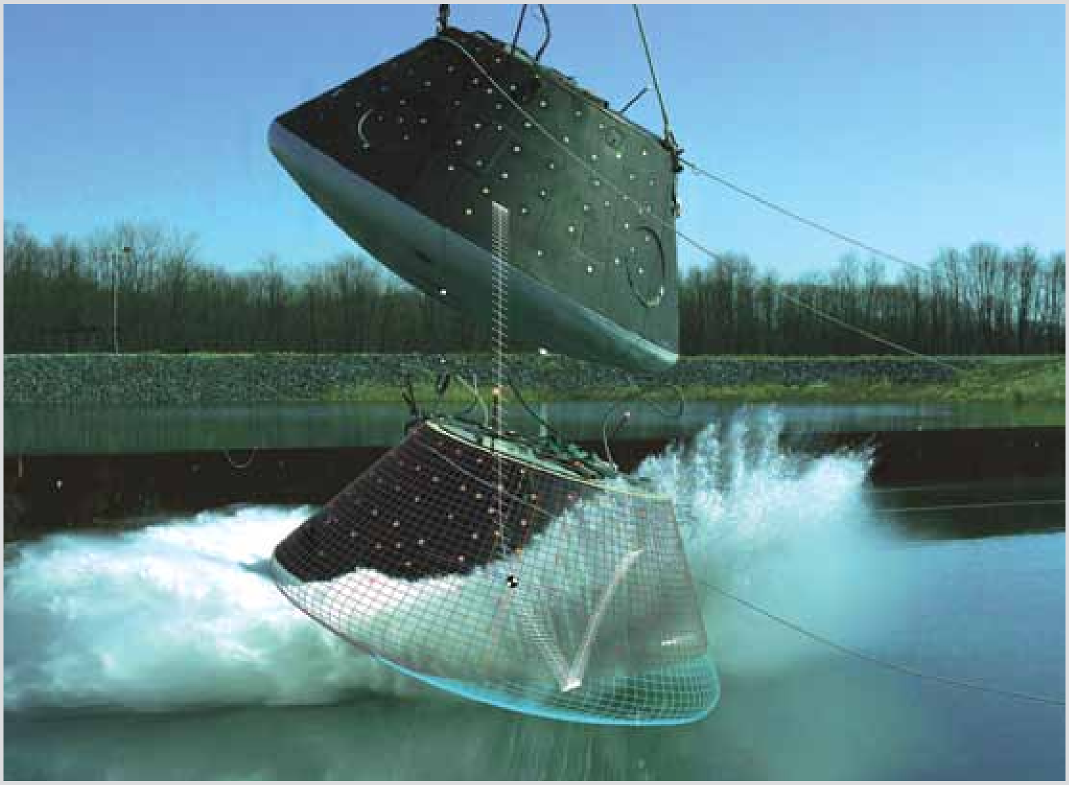
- Engineering Judgment: Exploit previous experience with a specific situation to declare that no additional analysis is required if a stability margin fails the requirement by only a small amount.
- Evaluation of Uncertainties: Conduct a "sanity check" to re-assess whether the uncertainties input into the analysis are realistic. In certain cases, the effects of correlated variables can be taken into account to reduce the level of uncertainties used in the analysis.
- Checking the Time to Double Amplitude: Determine if the vehicle will fly through the region of concern before the oscillations reach unacceptable amplitudes, in which case a lower margin may be acceptable.
- Use of Time-Domain Simulations: Exploit the high-fidelity non-linear time-domain models to prove that the vehicle exhibits acceptable behavior, even with programmed test inputs or other inputs to excite oscillations. Additionally, the loop gains and/or time lags can be increased in the simulation to evaluate the actual stability margins remaining.

GNC lessons learned on instabilities can be applied to future NASA projects, such as the space launch system.

Similar insights and lessons were obtained by the NESC's slosh assessment GNC team in consultation with industry. The NESC found that historically some launch vehicles have been successfully flown by industry with the known threat of slosh instabilities. The NESC learned that the Atlas-II launch vehicle was safely flown with linearly unstable (as viewed from a purely linear frequency-domain perspective) slosh modes.

The primary lesson learned during this assessment was that an FCS designer should not rely exclusively on frequency-domain approaches to verify/certify stable flight. Designers should use all the tools and techniques at their disposal, including the four previously identified. The use and application of the frequency-domain synthesis and analysis tools must be balanced with time-domain performance simulation tools and possibly other considerations. The same techniques mentioned above apply generally to the analysis and evaluation of any potential instability: propellant slosh modes, flexible structure modes, or aerodynamic instabilities encountered by vehicles flying through rapidly changing aerodynamic regimes.

For more information, contact Cornelius Dennehy (cornelius.j.dennehy@nasa.gov)



High-speed photogrammetry was used to precisely track a boilerplate Orion crew module (CM) in full-scale water drop tests. Vector overlays, based upon computer-aided design and photogrammetry measurements, were added to visualize the orientation, trajectory, maximum plunge depth, and wetted area of the CM.

New Photogrammetry Technique is Accurate and Adaptable

A new photogrammetry technique has been developed that allows accurate six degrees of freedom (6-DOF) orientation measurements to be made of large, moving rigid bodies.

This technique can provide data of vehicle dynamics or motions with accuracy equal to or better than inertial measurement units and has been used on multiple NESC-sponsored projects. Maximum flexibility is provided in choosing the number of cameras, the types of lenses, and the placement of those cameras in accessible locations for a flight experiment or ground test facility without overlapping camera view constraints.

The technique was developed to measure the separation of a full-scale Orion crew module (CM) from its protective forward fairing during NASA's Max Launch Abort System (MLAS) flight test. Photogrammetric analysis of the 6-DOF separation was a critical measurement for comparison with inertial measurement units. Conventional photogrammetry techniques require low-distortion lenses and overlapping camera views of the object of interest and could not be used on the MLAS test due to space constraints. Thus the new algorithm was developed, which used fish-eye lenses and nonoverlapping views. Later, the technique was used to accurately measure the position and attitude of a full-scale Orion CM during water entry testing at various entry angles and velocities. Again, multiple high-speed cameras were used with views that did not fully overlap. The algorithm was extended to accommodate different camera lenses, calibration methods, and more automated processing. Over 60 drops were recorded and processed.

Photogrammetric targets are first applied to the body and surveyed. Given that each camera observes a separate subset of the photogrammetric targets on the object of interest, if all those targets are constrained to the same rigid body, then a representative set of equations can be developed. The solution to the equations is the one unique 6-DOF orientation of the rigid object that results in the target patterns observed in all the cameras. Modern camera calibration techniques were employed by capturing and analyzing numerous images of objects with well-known structure, such as arrays of regularly spaced dots or squares. Finally, a robust target-tracking algorithm was implemented, which could follow targets from frame to frame, even in the midst of significant flying debris or water droplets. All these technologies were combined into a MATLAB/LabVIEW platform, which could be used at the test site immediately after an experiment. Measurement accuracy of the CM/fairing relative positions was to within 0.50 inch even after 16 feet of separation. Displacements with millimeter accuracy and attitude within hundredths of a degree were obtained for the water entry tests.

For more information, contact Kurt Severance (kurt.severance@nasa.gov)

Center of Gravity Determination Using Photogrammetry

Frequently, as part of a Structural Validation Test Program, the addition of test components as well as instrumentation can lead to some degree of uncertainty regarding the known position of the center of gravity (CG) of a test article. To assist the LS-DYNA model validation for the Orion boilerplate crew module (CM), an independent method of determining the CM CG was investigated. The CG, which serves as the origin for all six degrees of freedom measurements, is critical for test/model parameter correlation.

To support the task, a photogrammetric method was devised to measure the position of the CM at different hang angles using an asymmetric 2-point lifting strap **(Figure 1)**. Two lifting straps were constructed to provide hang angles of 20 and 30 degrees, respectively. The combination of the two straps provided eight unique positions from which the CM could be suspended. A key component of the technique was a plumb line suspended from the same lifting hook. The concept theorized the vector representing the plumb line, if extended, would pass through the CM and the CG would lie somewhere along that line. The plumb line visibility was maintained by attaching retro-reflective spheres along its length. By photogrammetrically measuring the plumb line position at the various hand angles, the plumb lines would intersect at a common point representing the CG. At each of the eight positions, the CM/plumb line were imaged and processed to find the position of the CM and the plumb line in a three-dimensional space. The resulting measurement data were consolidated to provide an array of line vectors representing the theoretical plumb line that intersect at the CG of the module **(Figure 2)**. To combat the effects of wind and motion on the plumb line, a redundant line not attached to the test article or crane was included to correct the potential error in the primary plumb line.

When processing the data, it must be considered the plumb line vectors are unlikely to actually intersect. To determine the best-fit CG, an algorithm that approximates the center by finding the point that minimizes the sum of the squared distances between that point and each of the plumb lines was developed. The results from this test have shown good correlation to the original computer-aided design-estimated CG and that verified independently with classic fixture methods. The results, as determined by this method, converged to sphere with radius less than 0.667 inch in all axis and are shown as an offset from the origin of 0.367 inch **(Figure 3)**.

This method could eliminate the costly and complex equipment required for CG determination via traditional methods. The technique lends itself very well to large bodies, oddly shaped bodies, and fragile flight hardware, and it can be executed much more quickly than traditional measurement techniques.

For more information, contact Thomas Jones (thomas.w.jones@nasa.gov)

Figure 1. CM in CG test configuration with plumb line(s).

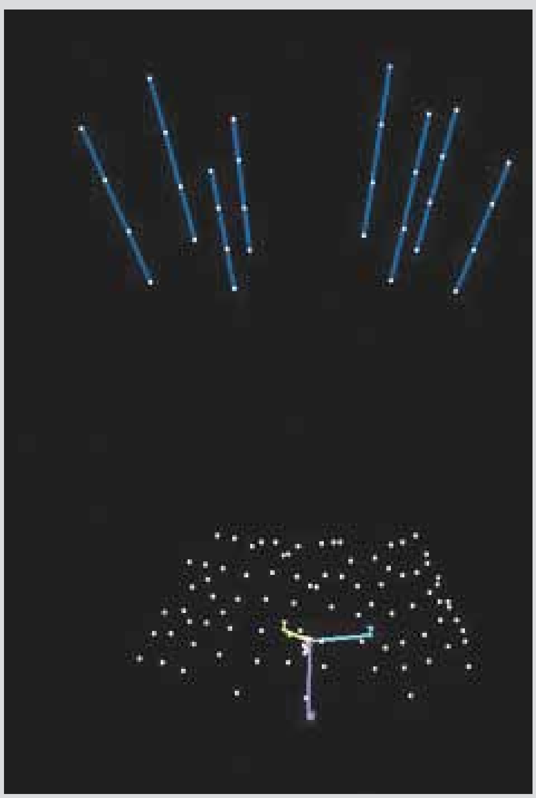


Figure 2. Consolidated data including vectors representing eight plumb lines.

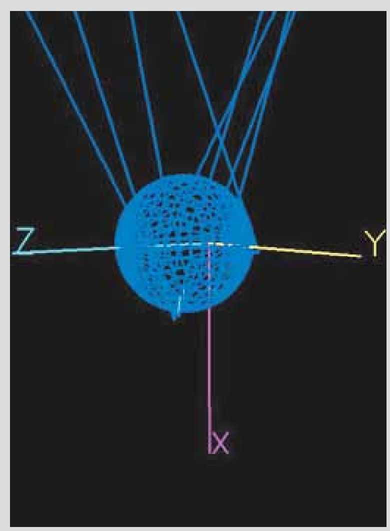


Figure 3. Intersecting plumb lines at CG. Inclusive sphere radius 0.667 inches. Center offset from origin 0.367 inches.

Statistical Sampling Plan Calculators

When engineers need to verify compliance with a design requirement using Monte Carlo simulation, they need to know how many trials to run and if the requirement was met. A set of plan calculators is now available to help. The requirement will outline the design conditions, the minimum reliability demanded, and the maximum probability of accepting a noncompliant design resulting from statistical error. The calculators will do the rest. The plan calculators are implemented as (beta-test) Excel spreadsheets. The calculators were developed from the literature on acceptance sampling — a statistical quality control technique originally intended for sampling inspection in production/supply-chain environments. The plans are appropriate for this original purpose, as well as for Monte Carlo applications in design.

For more information, contact Dr. K. Preston White (kpwhite@virginia.edu) or Kenneth Johnson (kenneth.l.johnson@nasa.gov)

Development of a Composite Pressure Vessel Laser Profilometry and Eddy Current Scanning System to Meet Manufacturing and Analytical Needs

Composite pressure vessels (CPVs) are used widely in spacecraft and other applications to obtain significant weight savings over metal pressure vessels. However, CPV variability has continued to be relatively high even though significant effort has been placed on ensuring manufacturing consistency. Additionally, there are concerns that liner flaws may go undetected, causing failure after being pressure cycled in service. Most manufacturers currently use fluorescent dye penetrant for liner flaw detection and borescopes for interior visual inspections. However, these methods are subject to human error and are not as quantitative as desired, making additional development of nondestructive testing methods desirable.

(Left photo) WSTF personnel, Paul Spencer, left, and Charles Nichols, right, configure a desktop system to do EC scanning of a liner defect standard. (Right photo) A 48-inch Orion service module CPV simulator in the tall delivery stage.

While the NASA Nondestructive Working Group started development of internal profilometers for CPV evaluation, the NESC Composite Pressure Vessel Working Group soon joined as a partner to gain analytical capabilities necessary to evaluate the mechanical response of CPVs. The WSTF has managed the project and handled testing, while the scanning hardware development was contracted to Laser Techniques Company, Redmond, Washington. A scanning station was first developed with a rotating interior sensor probe that accurately mapped and measured the interior cylindrical profile. The scanning station was later modified to also provide external profilometry plus eddy current (EC) scanning capabilities.

To perform external profilometry and EC scanning, the rotating interior sensor probe is easily removed and replaced with offset external sensors and a rotational stage spins the CPV (as seen in photo, left). An articulated probe and delivery system was also developed to allow CPVs with ellipsoid ends to be scanned from port to port, as developed first for the Orion service module CPVs (as seen in photo, right) and then the International Space Station (ISS) nitrogen oxygen recharge system (NORS) CPVs. System radial accuracy varies between approximately +/- 0.001 to 0.002 inch, depending on the port size and other restrictions. This allows pits, bulges, distortion, and the amplitude and periodicity of anomalies to be evaluated and then imaged with "laser vision." The EC system easily detects exterior cracks and defects ~0.001-inch deep on the surface of aluminum liners and sensors have been developed for evaluation of internal cracks and crack detection through the composite material. The flaw detection through the composite is greatly degraded, but sensitivity is to be quantified for various applications (involving JPL and LaRC). The NESC will also supply liners with fatigue cracks to help quantify the flaw detection capability.

The system has been used for CPV applications at WSTF and at CPV supplier facilities. It was used at a supplier facility to incrementally evaluate mechanical response as the liners were wrapped and then autofrettaged in support of ISS stress rupture testing. The system was also used in the NESC study that characterized the response of aluminum lined T1000 and IM7 carbon vessels to autofrettage and a new NORS system has been delivered to characterize their CPVs as a part of developmental testing.

For more information, contact Regor Saulsberry (regor.l.saulsberry@nasa.gov)

Improved Micrometeoroid and Orbital Debris Damage Prediction

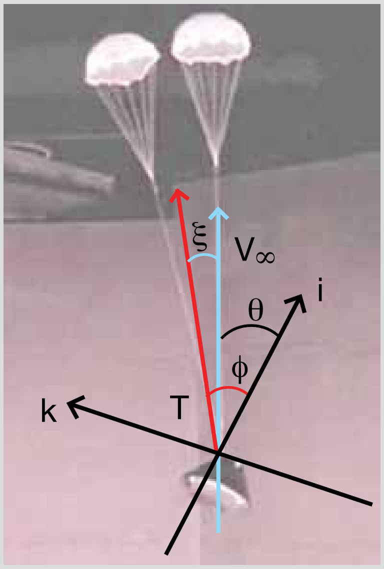
A tool developed by two members of the NESC team assessing improved International Space Station (ISS) micrometeoroid and orbital debris (MMOD) damage shielding designs will provide more accurate prediction of damage produced by MMOD impacts. Older equations used for MMOD damage prediction are based on limited data and are applicable only to a narrow range of shield materials and configurations. A new damage prediction tool was developed that more accurately predicts the hole size and crack length caused by a hypervelocity impact (HVI) on a pressurized spacecraft cabin or module. This tool, called the W-S hole/crack prediction model, was designed to be used within the application that calculates the risk of an MMOD-caused catastrophic failure. Like earlier models, the W-S model will provide results based on a given particle size, impact obliquity, and velocity. However, the new model also uses parameters associated with the shield configuration as independent variables. Typical MMOD shielding includes an outer shield called a bumper, an inner shield called the rear wall, and a space between the two called the standoff. There may also be intermediate shields or thermal insulation blankets between the bumper and the rear wall. The shield parameters that are included in the W-S model are those related to the material and geometry of the rear wall and bumper, the standoff distance from the bumper to the rear wall, and the mass and placement of any intermediate bumpers. The result is a generic damage predictor that can be universally applied to different shield configurations.

W-S model damage predictions compared to the results using older models show that while the newer predictions tend to predict larger hole sizes than previous models, HVI test data correlate more closely to the W-S predictions. The W-S equation is now being used for the ISS in calculating the risk of catastrophic MMOD damage to ISS modules, but in the future can be applied to other spacecraft with different MMOD shield configurations.

For more information, contact Dr. Joel Williamsen (jwilliam@ida.org) or Dr. William Schonberg (wschon@mst.edu)

Apollo Era Drogue Damping Estimation Technique

An analytical technique developed during the Apollo Program for predicting the effect of a drogue parachute on the vehicle's oscillatory motion was rediscovered and applied during an NESC assessment to the Orion crew module (CM) drogue system with improved prediction results over current methods. One of the prime functions of a drogue parachute is to stabilize and damp vehicle oscillations to provide a stable platform for main parachute deployment. When the drogue parachutes were deployed during the Pad Abort-1 (PA-1) flight, they produced more damping than was predicted by two-body 6 degrees of freedom simulations. To resolve this difference, the Apollo-era technique was resurrected and shown to accurately predict the full-scale motion.



Drogue resultant force acts in line with the free-stream velocity (red vector).

During PA-1, the CM initial orientation at drogue deploy had large oscillation angles and rates, as expected. The combined effect of the vehicle and drogue damping caused the system to damp much faster than preflight simulations had predicted. This faster flight damping was also predicted by wind tunnel tests on scaled models in the LaRC Vertical Spin Tunnel (VST). To explain this anomaly, the legacy tools and techniques used to analyze Apollo drogue flight test motion were resurrected. The legacy hypothesis is that the drogues will align with the total velocity vector at the attach point. This assumption was empirically verified by examining both VST and PA-1 measured relative motion of the drogue with respect to the CM. The legacy tool supports single-body simulations by modeling an effective drogue static and dynamic moment. Using these models, the single-body simulator accurately predicted the PA-1 oscillatory motion. Additional VST testing is scheduled to acquire the necessary data for the legacy method to further validate its applicability and to refine Orion drogue parachute performance predictions.

The basis of the Apollo legacy damping model is the hypothesis that the drogue parachute aligns with the resultant velocity of the attach point on the CM. This resultant velocity is the sum of the free-stream velocity plus the velocity induced by the angular rates of the system about its center of gravity (CG). The parachute damping results from a hysteresis in the moment arm of the parachute as the CM oscillates over a cycle. Simple equations for the equivalent static and dynamic moments about the system CG due to the drogue parachutes were recently derived. These equations provide a powerful preliminary design and analysis tool for use with drogue parachutes. It is noted that the Apollo legacy model is applicable only to smaller-sized parachutes such as drogue parachutes. The large parachute mass and associated air mass for main parachutes prevent the lateral motions required to align with the attach point velocity.

As a result of the accurate prediction of the PA-1 drogue motion, the Apollo legacy methodology has been adopted by the Orion Multi-Purpose Crew Vehicle Program for their drogue parachute performance predictions. This legacy tool plus recent improvements is now available to the NASA community.

For more information, contact Dr. David Schuster (david.m.schuster@nasa.gov)

Center Focus

The A-3 test stand under construction at SSC

Ames Research Center

Nans Kunz

NESC Chief Engineer at ARC

24:

ARC employees supporting NESC assessments

Ames Research Center (ARC) has a diverse set of capabilities and expertise and, thanks to involvement in the NESC's assessments and Technical Discipline Teams, this expertise is supporting a wide variety of Agency programs and activities. Some examples from this past year include tapping into ARC expertise in information technology to support the Department of Transportation National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation. Various throttle control system software modules were modeled and analyzed using tools that included ARC-developed software diagnostic programs. For aerodynamics, ARC has technical expertise and unique infrastructure, such as multiple wind tunnels and a supercomputer running state-of-the-art computational fluid dynamics (CFD) simulations/analyses. In this area, ARC has supported at least two significant NESC assessments this past year. In the beginning of the year, a special test was completed in the 11-foot Transonic Unitary Wind Tunnel that investigated rocket plume interaction from the Orion launch abort system. This test used hot high-pressure helium gas to simulate the rocket plumes while being tested at transonic speeds in the tunnel test section. In another assessment, ARC personnel are developing and conducting a wind tunnel test to verify and validate the CFD predictions related to wake flow with regards to characteristics and loads required in designing the Capsule Parachute Assembly System.

Working to Preserve Heritage Thermal Protection System Materials

Dr. Ethiraj Venkatapathy, Chief Technologist for the Entry Systems and Technology Division at ARC, brought his concerns to the NESC about the threat to future NASA missions posed by uncertainties in the continued availability of heritage carbon phenolic thermal protection system (TPS) material. The NESC formed a team that included NASA Technical Fellows to assess the problem. The team provided a recommendation to the Office of the Chief Engineer urging the Agency to immediately fund carbonizing all remaining heritage rayon before the carbonizing facility was shut down permanently; thereby ensuring critical mission needs are met in the future. By being receptive to issues such as sustainable TPS material availability and bringing those issues to the attention of Agency decision makers, the NESC played a vital role in maintaining a key capability. "This will enable NASA to conduct missions such as Mars Sample Return, Venus Landers, and Saturn Probes, and use the knowledge gained on those missions to address origin of life questions, the Venus-Earth-Mars connection, and the evolution of solar system," said Dr. Venkatapathy.

Matthew Gasch (left), Ethiraj Venkatapathy (middle), and Jay Feldman (right) analyze the manufacturing process requirements for chop molded carbon phenolic heatshield material.

Rick Alena conducts an experiment on a new wireless sensor network prototype.

Developing Wireless Sensor Networks for Spacecraft

Rick Alena, computer engineer, led an NESC team that developed new wireless sensor network technology suitable for structural health monitoring of composites used for aerospace vehicle structures. Using the latest ZigBee system-on-a-chip (SoC) technology, the development team interfaced piezoelectric strain sensors and micro-electric mechanical-based accelerometers to prototype circuits, updating the firmware to incorporate time stamps, raw data values, and engineering data values into the wireless data stream. Concepts for packaging the SoC in micro-miniature assemblies complete with multiple sensors for payload shroud structural monitoring were developed, meeting basic requirements for developmental and flight instrumentation. This technology was presented to the Ares Data Bus Study Team at MSFC for use onboard future heavy lift launch vehicles. In addition, a concept for payload shroud monitoring in flight was presented to the NESC Chief Scientist. "The NESC-sponsored work on wireless sensor networks has generated a number of innovative approaches for new health-monitoring technology for space exploration vehicles, adding new capability for strain, temperature, and acceleration measurements during wind tunnel and flight test," Mr. Alena stated.

Dryden Flight Research Center

Dr. James F. Stewart

NESC Chief Engineer at DFRC

Dryden Flight Research Center (DFRC) engineers supported numerous NESC activities that contributed to the success of the Agency's programs and projects. DFRC engineers are members of most NESC Technical Discipline Teams (TDT) and have supported numerous TDT activities, such as contributing to the development of a Community of Practice website for programmable logic devices as part of the NESC Avionics TDT. DFRC engineers supported the Guidance, Navigation, and Control (GNC) TDT and are developing a control system short course for NASA engineers that focuses on both classical and modern methods to meet the needs of NASA. The NESC engineers have supported the DFRC Independent Review Team for the Stratosphere Observatory for Infrared Astronomy (SOFIA) Telescope liquid nitrogen precooling system and procedures. This review ensured both the system and procedures were safe and could be used to support the SOFIA Program. The DFRC Advanced Structures Measurement Technology Group (ASMTG) received NESC awards for their outstanding contributions to the structural testing of the NESC Composite Crew Module (CCM).

10:

DFRC employees supporting NESC assessments

David McBride, DFRC Director (far left), and Dr. James Stewart (far right), present the NESC Group Achievement Award to (center, from left to right) Dr. Lance Richards, Allen Parker, Anthony Plazza, and Dr. Hon "Patrick" Chan of the ASMTG.

ASMTG Supports CCM Testing

Dr. Lance Richards, Allen Parker, Anthony Plazza, and Dr. Hon "Patrick" Chan of the DFRC ASMTG supported structural testing of the CCM. The group developed an innovative technique that enabled fiber optic strain sensors to be visualized onto a three-dimensional profile of a test article, namely the CCM door and hatches. It allowed the distributed strain measurement to be projected on the object's surface in real time. This technology has helped pave the way for new aeronautics research at DFRC and continues to aid researchers in monitoring critical areas of structures during testing. Dr. Lance Richards, the lead of the ASMTG and a member of the NESC Nondestructive Evaluation TDT since 2006, spoke for the group when he stated, "Working on the assessment team was an invaluable experience for our fiber optic sensing team both technically and personally. The experience provided our team a unique opportunity to work with the Agency's finest on a technically relevant and challenging project. We were amazed at the high level of performance, individually and corporately, as well as the technical success the project was able to achieve. We are very grateful for the opportunity to participate on a project of this magnitude." The DFRC ASMTG also applied this technique extensively while working on several projects post-CCM such as testing risk reduction simulated wing structures for DFRC's F-18 as part of NASA's aeronautics research. The technique has been used to visualize pressure-induced strain changes of the composite overwrapped pressure vessels at WSTF.

Enhancing and Applying GNC Skills

Chris Regan, a controls engineer at DFRC, served on a 1-year detail as an NESC Resident Engineer. He supported key NESC assessments and participated in the NESC GNC TDT. "The experience I had with the NESC allowed me to participate in diverse multi-Center, multidisciplinary teams working in fast-paced environments," Mr. Regan stated. Mr. Regan performed trajectory reconstruction and data analysis tool development for the NESC's Crew Module Water Landing Modeling Assessment, where an instrumented full-scale Orion boilerplate crew module (CM) was dropped at various water entry conditions to provide data for anchoring Orion CM structural models. "I hadn't been exposed to the space side of the house prior to working with the NESC. Nor had I worked on engineering teams with members across the Agency. The contacts within the Agency and industry helped me develop new skills and expertise that I can apply to future DFRC projects," Mr. Regan stated. Mr. Regan also extended his skills by conducting software analysis and hardware testing for the NESC in support of the Department of Transportation National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation.

Former NESC Resident Engineer Chris Regan.

Glenn Research Center

The Glenn Research Center (GRC), provided a broad spectrum of technical expertise in support of NESC assessments and the NESC Technical Discipline Teams (TDTs). In support of the Orion Crew Module (CM) Water Landing Modeling Assessment, a boilerplate CM was instrumented to measure accelerations, pressures, and strains during water drop tests. GRC experts used this data to validate analytical models predicting CM/water interactions during impact. GRC continues to provide expertise in tribology and mechanical components to numerous NESC activities including the International Space Station (ISS) solar alpha rotary joint, the ISS ammonia cooling pump, and is currently utilizing the GRC vacuum roller rig to investigate wear and debris generation in the James Webb Space Telescope near infrared spectrograph shutter positioning mechanism. GRC also conducted a bonded element test of the low impact docking system in support of the Composite Crew Module (CCM) Test and Verification Team. Digital image correlation photogrammetry was used to provide a more accurate evaluation of design allowables and margins, thus guiding analytical and test verification approach recommendations for the Orion Multi-Purpose Crew Vehicle (MPCV) Program.

51:

GRC employees supporting NESC assessments

Dawn C. Emerson

NESC Chief Engineer at GRC

Readying MSL Instrumentation for Launch

NASA missions often push hardware to extremes, and the Mars Science Laboratory (MSL) is no exception. During development testing, high-speed vacuum pump bearings failed unexpectedly putting delivery at risk. Despite significant efforts, little progress in understanding the problem was being made. The NESC Mechanical Systems TDT member, Dr. Christopher DellaCorte, enlisted the help of colleague Dr. S. Adam Howard to model the rotordynamics of the pump and its bearings providing vital guidance to the development team in resolving bearing assembly, bearing preload, lubrication, and rotor balancing issues. The working pumps have passed qualification tests and are waiting to launch on the MSL. Dr. Howard is leading an effort to bring advanced bearing modeling software to other NASA engineers to aid future projects.

Adam Howard (left) and Chris Dellacorte of the GRC Tribology and Mechanical Systems Branch review the roto-dynamics model of a MSL 100,000 rpm vacuum pump.

Investigation of Orion CM Crew Safety

Dr. Charles Lawrence, a structural dynamicist at GRC, has been a member of several NESC teams involved with crewed spacecraft safety. His first involvement with the NESC was with the Orion CM water versus land landing study and later he worked on the Crew Module Water Landing Modeling Assessment. "This was an amazing experience being exposed to all aspects of vehicle landing including design issues, cost and safety, as well as having the opportunity to work with experts across the Agency including Apollo astronauts and engineers." Dr. Lawrence has also worked with the NESC on developing design options and safety standards for crew protection, a vibration isolation system for attenuating thrust oscillation from the Ares launch vehicle, and an assessment of analytical tools for predicting Orion CM structural response during water landings. "The water drop testing we performed under this assessment was an amazing opportunity to validate our numerical simulations with actual water drop test data and then have the results used by Orion CM designers for an actual spacecraft design."

Dr. Charles Lawrence

Providing Expertise to the NESC Technical Discipline Teams

Dr. John Thesken of the Applied Structural Mechanics Branch contributes expertise in composite structures, test, verification, and flight hardware certification as a member of the NESC Composite Pressure Vessel (CPV) Working Group and the NESC CCM Test and Verification Team. His recent NESC work resulted in more accurate life predictions for CPV flight hardware flying on the Juno probe to Jupiter. For CCM, GRC contributed test article design analysis, element testing, and coordinated the implementation of acoustic emission and structural health monitoring for the full-scale tests. Ties to strong discipline networks help translate valuable lessons learned to the Orion MPCV Program and other flight programs. "Composite structures development requires a multidisciplinary team and the resources to build and test; I am grateful for the opportunity the NESC has given us to achieve these goals."

From left, Justin Littell, ATK Space Systems, Chris Burke, research technician, and John Thesken examining a broken specimen of CPV.

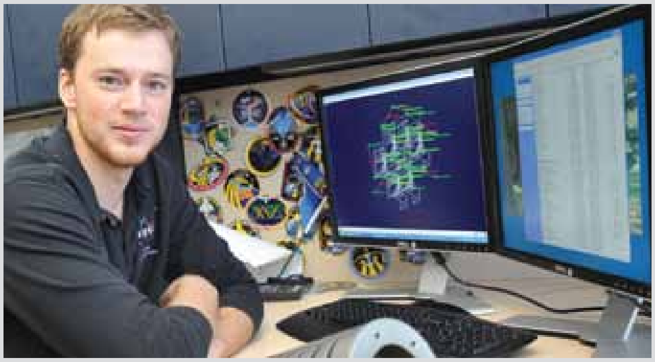
Goddard Space Flight Center

Timothy G. Trenkle
NESC Chief Engineer at GSFC

Dr. John H. Day
NESC Chief Engineer at GSFC (Acting)

74: GSFC employees supporting NESC assessments

The Goddard Space Flight Center (GSFC), including the Wallops Flight Facility (WFF), participated in a wide range of NESC activities during 2011 for human exploration and space operations, as well as robotic space and Earth science missions. The NASA Technical Fellows for Avionics; Electrical Power; Guidance, Navigation, and Control; Mechanical Systems; and Software are resident at GSFC. The NESC obtained expertise from around the Agency to perform independent technical assessments and reviews, and provided technical support to GSFC activities, including the sample analysis at Mars instrument, wide range pump for the Mars Science Laboratory, near infrared spectrometer microshutter mechanism, mid-infrared instrument cryocooler disturbance, and sunshield for the James Webb Space Telescope, reaction wheel assembly lubricant for the Tracking and Data Relay Satellite System, cross-track infrared sounder instrument frame for the Joint Polar Satellite System, Hubble Space Telescope Attitude Observer, and Taurus II launch pad testing at WFF. NESC discipline activities that benefited from multiple GSFC projects included improvements in fastener design, wireless connections, thermal databases, fault management, and pyrovalve reliability.



Cory Powell of the GSFC Mechanical Systems and Simulation Branch conducted ADAMS analysis for the NESC assessment.

Automatic Dynamic Analysis of Mechanical Systems for Crew Impact Attenuation System

Cory Powell has been a mechanical engineer with the GSFC Mechanical Systems Analysis and Simulation Branch for over 5 years. Previously, as a GSFC co-op student, Mr. Powell learned the Automatic Dynamic Analysis of Mechanical Systems (ADAMS) software because there was no one in his branch experienced with this software tool. When the NASA Technical Fellow for Mechanical Systems determined that ADAMS analysis may be needed for the NESC's Orion seat attenuation and thrust oscillation assessment, Mr. Powell worked closely with a senior engineer at the Johns Hopkins University Applied Physics Laboratory to become a proficient ADAMS user. Along with Mr. Ben Emory and other mechanical engineers in his branch, Mr. Powell analyzed various landing conditions for this assessment. Mr. Powell stated, "This NESC assessment highlighted the importance of this type of analysis and now my branch has four advanced ADAMS users. After the analysis was completed, I was asked to be the assessment vibration test lead. This was a great experience. It allowed me to gain leadership experience and create contacts across multiple NASA Centers and universities. I also visited JSC, LaRC, and the Naval Warfare Center at Dahlgren. In my short time at NASA, this project taught me more than any other project. I look forward to working with the NESC again."

Test Support to the NESC Study of Reported Unintended Acceleration in Toyota Vehicles

Michael Bay is a GSFC systems engineering contractor with over 30 years of experience with the design, development, and operations of human and robotic space missions. Mr. Bay has contributed to many NESC activities, including the Crew Exploration Vehicle Smart Buyer Design Team at GSFC's Integrated Mission Design Center and systems engineering and electrical systems volumes for the Design, Development, Test, and Evaluation Considerations for Safe and Reliable Human-Rated Spacecraft Systems. Recently, Mr. Bay participated in the NESC's technical support to the Department of Transportation National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation. He worked with the NASA Technical Fellows for Avionics and Software to systematically evaluate functional failures in various scenarios using test beds at GSFC and Toyota test vehicles. Mr. Bay stated, "There are many benefits of serving on NESC assessments. Challenging assessments provide a unique opportunity to work with engineers from different NASA Centers, industry, and academia. These new peers become friends and a valuable resource for future collaboration. Working among team members from other Centers also broadens my experience base and allows me to learn new techniques. I have learned so much over the last few years, and it has been fun and challenging as well."

Michael Bay examines engine response to accelerator inputs using Toyota's onboard diagnostic port.

Brian Abresch of the Wallops Electrical Engineering Branch tests avionics used on the CM water drop assessment.

Avionics for Crew Module Water Landing Modeling Assessment

Brian Abresch has been an electronics engineer in the Wallops Electrical Engineering Branch for more than 10 years. He has been a significant contributor to multiple NESC projects, where he served as the avionics integration and test lead for the Max Launch Abort System (MLAS) and the avionics lead for both phases of the Crew Module Water Landing Modeling Assessment (CMWLMA). The design, build, and integration of the avionics hardware for MLAS and CMWLMA were completed at the engineering and integration facilities at WFF. Mr. Abresch stated, "I have thoroughly enjoyed working with the NESC and all NASA Centers to provide the Orion Multi-Purpose Crew Vehicle Program with critical empirical data and program risk mitigation. The NESC has allowed me the opportunity to participate on assessments that provided critical data to high profile NASA-wide development efforts. This is a departure from many of the missions that WFF typically supports, which are generally highly specific and localized science missions. It was exciting to know that the information collected was part of a much larger and broader effort to send NASA's astronauts beyond Low Earth Orbit. The results of the MLAS and CMWLMA Projects will serve NASA and the private industry for many years to come."

Development of Field Programmable Gate Array Training for the Agency

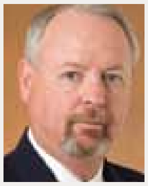
Renee Reynolds and Andrea Dye are engineers with the GSFC Electrical Engineering Division. They are working with the NASA Technical Fellow for Avionics to develop training material that would expand the skill set of NASA engineers in programming with microcontrollers and field programmable gate arrays (FPGAs).

Ms. Dye started at GSFC as a co-op student, and in 2008 she converted to a full-time engineer with the Electrical Systems Branch after earning an electrical engineering degree. Her GSFC responsibilities include development of electrical ground support equipment for the Global Precipitation Mission, Magnetospheric MultiScale Mission, and Astro-H Mission. Ms. Dye stated, "Working with the NESC has allowed me to interact with individuals from KSC and learn the atmosphere amongst the engineers, working on a multi-Center team. It also allows me to work with a greater range of people both at GSFC and KSC. The opportunity to support the NESC has been rewarding and fulfilling. I have high hopes that this endeavor will allow greater collaboration between the Centers and will allow other engineers to have the opportunity to expand beyond their current skill set."

Ms. Reynolds began her professional career with the GSFC Flight Data Systems and Radiation Effects Branch in 2001 as an electrical engineer. Since joining NASA, she has earned her master's degree and received many awards for her contributions as FPGA designer and/or electronics board designer for major flight projects such as Swift Burst Alert Telescope, Solar Dynamic Observatory, Lunar Reconnaissance Orbiter, and Hubble Space Telescope Servicing Mission 4. Ms. Reynolds stated, "I plan to leverage from my work developing the Digital Design Training Module to provide a quality training product for the NESC. As a result of this opportunity with the NESC, I am able to work on a multi-Center team and share technical knowledge with engineers from other NASA Centers."

Renee Reynolds (center) and Andrea Dye (right), work on a FPGA trainer board for the NESC FPGA Development Training Course with Oscar Gonzalez, NASA Technical Fellow for Avionics (far left) and Chris Iannello, Electrical Power Discipline Deputy.

Jet Propulsion Laboratory



R. Lloyd Keith

NESC Chief Engineer at JPL

The Jet Propulsion Laboratory (JPL) participated in the NESC assessments for the Science and Human Exploration and Operations Mission Directorates and supported the NASA Technical Fellows and their Technical Discipline Teams (TDTs). JPL led the Orion crew module (CM) water landing testing with the second phase of testing now complete. The results have improved the CM design models and CM design and has and will continue to influence future testing plans and design options. The NESC Composite Pressure Vessel Working Group (CPVWG) has developed a test plan for stress rupture (a composite overwrapped pressure vessel failure mode) based on needs identified in previous NESC assessments and is proceeding with a stress rupture model development program. JPL supported NESC assessments for the Science Mission Directorate, which include software tools, battery usage in operational missions, and pyrovalve reliability. JPL is also developing the thermal performance database to gather historical data on thermal protection system performance and provide an easy access to that data. The Robotics TDT, led by the NESC Chief Scientist at JPL, is working several tasks to advance robotic exploration, including the entry, descent, and landing (EDL) task, in which a database was developed to capture at-risk EDL data to benefit future spacecraft designs.

93:

JPL employees supporting NESC assessments

Learning through the NESC Assessments

Brandon Florow is a former NESC Resident Engineer who participated in several interesting NESC studies. Mr. Florow worked on the composite overwrapped pressure vessel (COPV) stress rupture testing and also acted as the test conductor for the first phase of the Orion CM seat attenuation strut testing. In addition, he prepared the test plans and supported all three phases of strut testing. Mr. Florow was also on the Quick-Look Data Team and the Strain Gage Instrumentation Team for the Crew Module Water Landing and Modeling Assessment. “Being a young engineer, the NESC offered me an opportunity that I couldn’t get anywhere else. It allowed me to work with system experts both within and from outside my field, gain an overall Agency perspective, and expand my network of colleagues.”

Brandon Florow

Engineering Safer Landing Systems for Spacecraft

John Baker, systems engineer, has studied and quantified the risks in multiple versions of Orion CM landing systems. “I have led a number of successful assessment teams since 2006 for the NESC that have resulted in design changes to the Orion CM,” Mr. Baker stated. These studies included risk trades between water and land landing variants. His most recent assessment involved Orion CM water landing impacts and how to model them. “I had a diverse inter-Center team that worked very hard and produced an outstanding test data set for the Orion Multi-Purpose Crew Vehicle Program and other future teams that want to land capsules back on Earth. Leading teams for the NESC has been a real honor for me and has broadened my experience base both technically and as a manager.”

John Baker

Improving Engineering Knowledge of Composite Pressure Vessels

Dr. Lorie Grimes-Ledesma is the chair of the NESC CPVWG. The CPVWG is chartered to understand and communicate issues and risks associated with legacy and state-of-the-art COPVs and all-composite tanks. In the 4 years that Dr. Grimes-Ledesma has led the Agency-wide CPVWG, the group has provided technical support to several programs and projects throughout NASA including the International Space Station, Orion Multi-Purpose Crew Vehicle, the Juno Probe, and the Global Precipitation Measurement Satellite. Dr. Grimes-Ledesma is also the technical lead for the NESC COPV life prediction model development task and supports the NESC Materials TDT. Dr. Grimes-Ledesma’s engagement with the CPVWG has enabled her to learn from and participate in solving a larger range of issues that span the NASA community.

Dr. Lorie Grimes-Ledesma examines composite pressure vessels undergoing life testing at WSTF.

The NESC's boilerplate Orion crew module is hoisted to drop height

Johnson Space Center

Dr. Nancy J. Currie

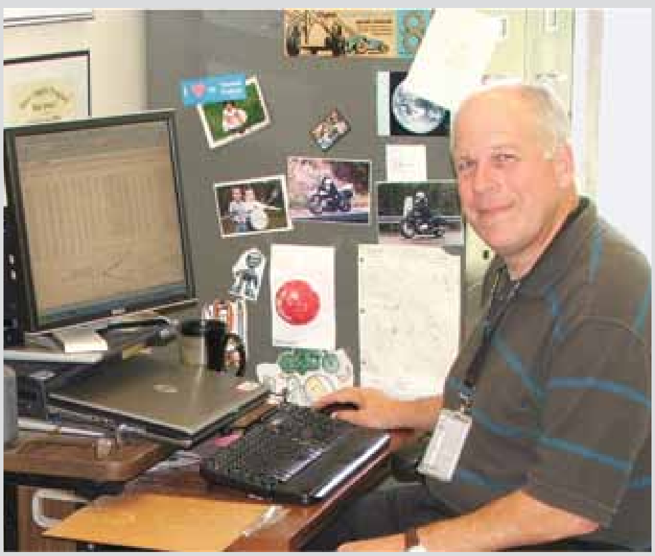
NESC Chief Engineer at JSC

The Johnson Space Center (JSC) and the White Sands Test Facility (WSTF) provided engineering analysis, design, and test expertise for the safe completion of the Space Shuttle Program (SSP); supported continuous operation of the International Space Station (ISS); and participated in the development of the Multi-Purpose Crew Vehicle (MPCV) spacecraft as well as other new systems. The NESC personnel at JSC supported missions in real time on both the SSP and ISS Mission Management Teams. The NESC Deputy Director for Safety and NASA Technical Fellows for Life Support/Active Thermal, Loads and Dynamics, and Passive Thermal are resident at JSC. The Technical Fellows at JSC provided key expertise to publicly released Agency roadmaps spanning 14 technology areas and supported presentations to the National Research Council. These Technical Fellows, along with Technical Fellows in Nondestructive Evaluation, Materials, and Structures and their Technical Discipline Teams, led independent analyses to investigate the root cause of the SSP external tank intertank foam and stringer anomaly. Their support extended throughout the process of resolving this issue, including the STS-133 delta Flight Readiness Review and STS-134 and STS-135 missions. The NESC personnel have contributed to transitioning and advancing exploration and were involved in MPCV spacecraft entry/landing systems, thermal control and protection, life support, and loads/dynamics. The NESC technical expertise was also applied at commercial crew development design reviews and technical interchange meetings.

57:

JSC employees supporting NESC assessments

In addition, the NESC engaged in several assessments and tests at JSC's WSTF in areas including pyrovalve booster interface temperature measurements and reliability assessments for expendable launch vehicle payloads, testing and analysis of composite pressure vessels (CPV), and development of a laser profilometer that maps defects on both the interiors and exteriors of cylindrical CPVs.



Dr. Eugene Ungar of the JSC Crew and Thermal Systems Division.

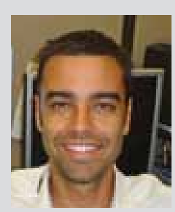
NESC TDT Support to James Webb Space Telescope

Dr. Eugene Ungar is a member of the NESC's Life Support/Active Thermal Technical Discipline Team and led the NESC's multi-Center JWST Sunshade Venting Analysis Team. His team independently assessed the analyses and tests being used by the JWST Program to demonstrate that the ascent venting of the JWST Kapton film sunshade will be efficient enough to prevent the sunshield membrane from being overpressurized and damaged. The team performed an informal blowing test to gain more understanding of the billowed shape of the folded and secured membranes during ascent and also tested membrane Helmholtz instability. These key tests allowed the team to conclude that longitudinal flow along and within the stowed membrane was unlikely to lead to flapping instabilities. "Working on a multi-Center team expands your horizons," Dr. Ungar stated. "Stretching technically into a field unrelated to your area of expertise is challenging. Taken together, they result in a very fulfilling task."

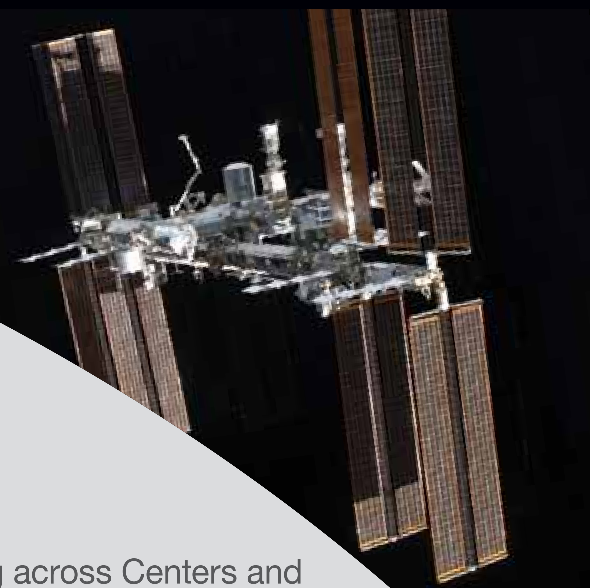
> "... the efficiency, broad expertise, and a team-oriented atmosphere led to the success of the assessment effort"
> — *Marshall Neipert*

ISS Radiator Face Sheet Failure Investigation

Marshall Neipert, aerospace engineer, was a key member of the NESC root cause investigation for the ISS radiator face sheet failure. He leveraged expertise at several Centers to understand and organize available data. With limited post-event data and on-orbit imagery and other measurements, he developed a physics-based LSDYNA model of a radiator pressurized to failure, which showed the failure propagation and final state of the face sheet. The model demonstrated many of the failure characteristics observed in the on-orbit radiator imagery and its usefulness in assessing the plausibility of a pressure event as a root cause. "To develop these techniques, I leaned on modeling experts at GRC and ARC. I have since used some of the techniques on the MPCV Program. The efficiency, broad expertise, and a team-oriented atmosphere led to the success of the assessment effort," Mr. Neipert stated.



Marshall Neipert



Launch Abort System Design

Dr. Jennifer Madsen

Joseph Cook

The NESC is engaged in a conceptual design effort for development of a launch abort system risk mitigation flight test vehicle. Dr. Jennifer Madsen of the Aeroscience and Flight Mechanics Division serves as the lead for the guidance, navigation, and control development, and Joseph Cook, Energy Systems Division, is the lead for design of the attitude control propulsion system. Both Dr. Madsen and Mr. Cook cited the benefits of working on a multi-Center project. “Working across Centers and across disciplines allows for the sharing of tools and analysis techniques to benefit the team members and the technical product,” Dr. Madsen observed. Mr. Cook has found the work “refreshing” and noted, “It’s nice to work in such a positive environment with everyone pulling together to succeed.”

> “Working across Centers and across disciplines allows for the sharing of tools and analysis techniques to benefit the team members and the technical product.”
> — *Dr. Jennifer Madsen*

Pyrotechnic Testing and Analysis

Regor Saulsberry of the WSTF Laboratory Office led two pyrotechnic assessments for the Propulsion Technical Discipline Team (TDT). The first, the Pyrovalve Booster Interface Temperature Measurement Assessment, compared legacy aluminum primer chamber assemblies (PCAs) against a new stainless steel PCA and provided other high-value data to programs. The test data indicated that the stainless steel PCA with V-shaped flame channels averaged 316 C (600 F) hotter at the booster charge interface than the aluminum PCAs with Y-shaped channels. When the two NASA standard initiators were fired simultaneously, neither channels produced a booster interface temperature high enough for reliable ignition. Ignition temperatures were adequate with firing skew greater than 250 microseconds, but a larger margin was recommended for flight applications. The second, the Pyrovalve Reliability Assessment for Expendable Launch Vehicle Payloads, used experts from several other TDTs and Centers to provide needed guidance for NASA payload safety policy regarding safe pyrovalve use in payloads propulsion systems using hazardous propellants. “It is great to have Technical Fellows with strong TDTs available to us,” explained Mr. Saulsberry. “This made the right technical resources available in a very timely manner.” Mr. Saulsberry also helped develop nondestructive laser profilometers and eddy current scanners to characterize defects in composite pressure vessels.

WSTF Pyrotechnic Testing and Analysis Team analyst, John Anderson (right) presents a finite element analysis to assessment lead Regor Saulsberry (center), Steve Woods, Expendable Launch Vehicle Deputy Lead (left), and Steve McDougle PCA Deputy Lead, (seated).

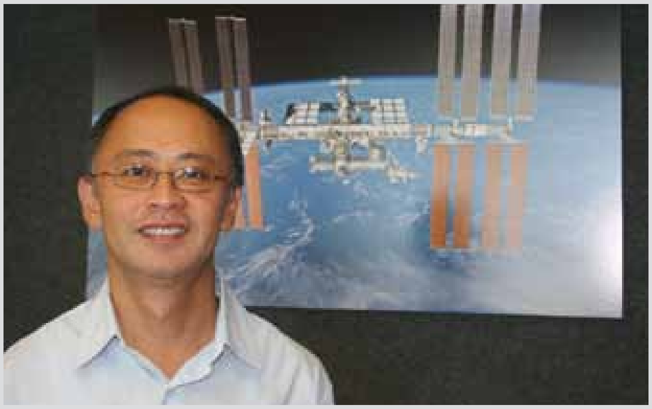
Kennedy Space Center

Stephen A. Minute

NESC Chief Engineer at KSC

52: KSC employees supporting NESC assessments

The NESC was involved in multiple activities and projects at Kennedy Space Center (KSC). Likewise, KSC continues to provide support and expertise to a wide variety of NESC assessments and testing across the Agency. KSC engineers provided expertise on 12 different NESC Technical Discipline Teams (TDT), including Electrical Power, Flight Mechanics, and Loads and Dynamics. The KSC expertise plays a role in resolving many of the Agency's difficult problems and was engaged in a variety of NESC assessments and projects affecting ground processing and operations at KSC, including space shuttle external tank (ET) stringer cracks; ET hydrogen vent umbilical leakage; orbiter auxiliary power unit heater anomaly; Commercial Crew Program requirements development and partner insight support; Doppler radar profiler for launch winds; ground and launch systems processing technology roadmap review; and avionics embedded electronic systems design training.



Dr. Phillip Tang of the Electrical Division in KSC engineering.

Going Where the Evidence and Data Leads You

Dr. Phillip Tang, an electronics engineer in the Engineering's Electrical Division, supported the NESC effort on the Department of Transportation National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation. He performed tests on various models of engine control simulators for both test and complaint vehicles. Together, the NESC team determined the effects that faulty signals have on the engine control module and the resultant throttle position/unintended acceleration. The team modeled and analyzed the various circuit parameters and then validated their analysis and failure scenarios through testing. Not only did this effort aid the National Highway Traffic Safety Administration in their technical investigations, it also fostered NASA inter-Center and inter-Agency working relationships. Dr. Tang stated the one lesson he learned was "Go where the evidence and data leads you."

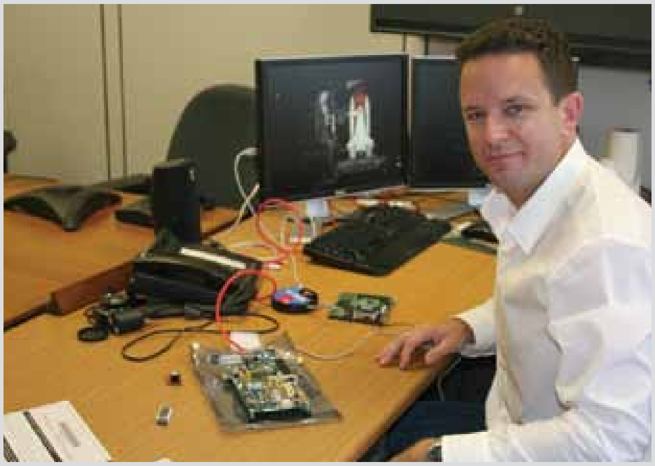
Predicting Rocket Plume Impingement on Launch Pad Structures

Dr. Bruce Vu, fluid systems lead in the Mechanical Engineering Division's Design Analysis Branch, was an active member of the NESC's multi-Center/industry partner assessment of Orbital Sciences Corp. (OSC) Stage Testing Plan for Taurus II at GSFC's Wallops Flight Facility. He developed a new capability in predicting rocket plume exhaust with chemical reactions. The capability to make accurate prediction of plume exhaust is important in the thermal analysis of ground systems — accurate plume definition leads to accurate plume impingement prediction on launch pad structures. The new capability uses finite-rate chemistry to accurately predict the launch-induced environment due to combustion of fuel and liquid oxygen. "Not only did I contribute to the project, but I also learned from other team members, especially how the commercial space industry conducts their business." The collaboration with OSC led to a technical paper on this new predictive capability.

Dr. Bruce Vu

Developing Agency-Wide Embedded Electronics Skills

Dr. Christopher Ianello serves as the Discipline Deputy for the Electrical Power TDT and is also an active member of the Avionics TDT. At KSC, he is a Deputy Chief Engineer for the Commercial Crew Program. He supported many of the NESC assessments with both TDTs and has employed laboratories at KSC, GSFC, and MSFC. With the Avionics TDT, he is implementing a discipline stewardship initiative to develop new skills in embedded electronics through an initial startup class at KSC with hopes of expanding across the Agency. "The NESC, in a few short years, has done more to connect discipline specialists Agency-wide with one another than any previous activity I have been a part of."



Dr. Christopher Ianello is developing an Agency-wide embedded electronics course.

Langley Research Center

Walter C. Engelund
NESC Chief Engineer at LaRC

Langley Research Center (LaRC) continues to support the NESC mission to address the Agency's and nation's high-risk programs and projects. LaRC personnel have contributed technical expertise in the areas of structures; materials; nondestructive evaluation; flight sciences; fabrication technology; loads and dynamics; computational fluid dynamics; mechanisms; guidance, navigation, and control; flight mechanics; and avionics. NESC activities at LaRC include the launch abort system risk mitigation flight test vehicle, where preliminary design has been developed to provide flight validation of the capsule abort option using actively controlled systems; autonomous aerobraking capability development; composite crew module analysis; Orion crew module structures analysis and water landing testing; shell buckling knockdown factor development from large-scale testing; space shuttle external tank stringer nondestructive testing and analyses; flight simulation model exchange; and International Space Station solar array boom analysis. The NASA Technical Fellows for Aerosciences, Flight Mechanics, Materials, Nondestructive Evaluation, and Structures are resident at LaRC.

171:
LaRC employees supporting NESC assessments

Jay Brandon
NESC Chief Engineer at LaRC (Acting)

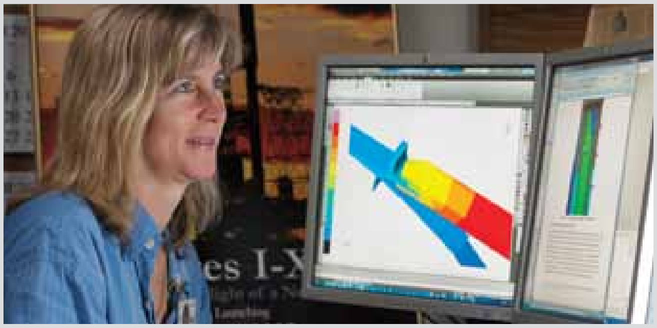
Launch Abort System Attitude Control Development

Gene Heim is the flight mechanics lead for the launch abort system risk mitigation flight test vehicle activity. As part of his duties, he has organized an experienced team consisting of members from the Max Launch Abort System (MLAS) and Ares I-X Flight Test Programs and has helped in the development of models and simulations being used to design and analyze the launch abort system. His analysis has impacted the architecture of the MLAS concept by demonstrating the benefits of adding roll control to the attitude control system. Mr. Heim has used his creativity and ingenuity in developing plans for reducing risk of the eventual flight demonstration, including the reuse of core models validated during the successful Ares I-X Flight Test Program, and plans for dynamic wind tunnel tests to assess closed-loop control of the system. “This project has given me the opportunity to work with extraordinary people across the Agency, and see sides of NASA I had not experienced before.”

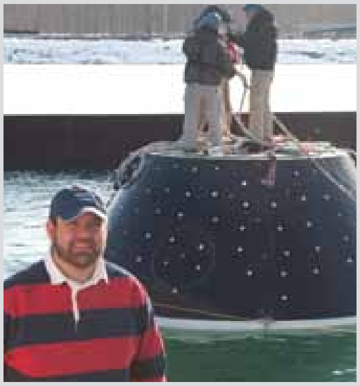
Gene Heim

Thermal Model Development

Ruth Amundsen, aerospace engineer, is a member of the Passive Thermal Technical Discipline Team, and was the NESC thermal lead for the space shuttle external tank stringer investigation. For this assessment, she was responsible for developing a thermal model of the cracked stringer area around the liquid oxygen tank and subjecting it to the same conditions as on the day of the crack, as well as test conditions that were used to correlate the models. Ms. Amundsen mapped the thermal variations for all the transient timelines and provided results to the structural lead, who analyzed the levels of stress and deflection due to those thermal gradients. The thermal model was compared to the tanking test data with excellent correlation. The complexity of the model needed, coupled with the short time span available, forced the improvement of methods for re-using a structural mesh for portions of the thermal model. Analyses were conducted on a desktop PC running the Thermal Desktop software, which is used Agency-wide. “The experience of comparing the thermal models done by three different organizations using different tools and methods was very educational. It was exciting, fast-paced work.”



Ruth Amundsen with thermal modeling software.



Kurt Severance with boilerplate Orion CM at the Aberdeen Test Center.

Applying Photogrammetry to Spacecraft Landing

Kurt Severance is a photogrammetry analyst responsible for computing the rigid body motion for all the drop tests in phase I and phase II of the Crew Module Water Landing Modeling Assessment (CMWLMA). By extending a photogrammetry technique originally developed for the MLAS flight analysis, he measured the six degrees of freedom motion of the crew module during freefall, water contact, and partial submersion. These highly accurate data products became the ground truth for comparison to all other measured datasets. “I thoroughly enjoyed being a member of the high-performing CMWLMA team. The success of the photogrammetry was the result of an effective collaboration among personnel in the NESC, LaRC Engineering Directorate, LaRC Research Directorate, LaRC Office of Chief Information Officer, WFF, and the Aberdeen Test Center.”

Marshall Space Flight Center

Steven J. Gentz

NESC Chief Engineer at MSFC

The Marshall Space Flight Center (MSFC) has provided engineering, scientist, and technician support to over 35 NESC assessments and investigations. These investigations involved the areas of exploration systems, space operations, science, and crosscutting discipline activities. Some of the more significant investigations include: shell buckling knockdown factor testing, sounding rocket sustainer motor design and development, Taurus II stage testing, SSC A-3 test stand structural analysis, cross-track infrared sounder instrument frame fabrication, Doppler radar profiler data analysis, and Orion launch abort system risk mitigation. The NASA Technical Fellow for Propulsion, and the Discipline Deputies for the Human Factors and Nondestructive Evaluation Technical Discipline (TDTs) are resident at MSFC. MSFC provides critical support to 15 of the NESC TDTs with over 100 engineers and scientists. Additionally, a MSFC employee served as an NESC resident Engineer.

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MSFC employees supporting NESC assessments

Developing a New Sounding Rocket Sustainer Motor

Ben Davis and Dale Jackson, aerospace engineers, have been working at NASA for 4 and 5 years, respectively, and are contributing to the solid rocket sustainer motor (SRSM) development through the design of the nozzle assembly and propellant grain and igniter. This development enabled Mr. Davis to participate in systems engineering activities with groups across MSFC. He has gained experience collaborating with subject matter experts at other Centers, federal agencies, and industries on topics ranging from propellant casting/curing to nozzle hardware cost and schedule data. Mr. Davis stated, "The NESC SRSM Program has benefited me by offering valuable experience in solid rocket motor design and systems engineering. No two motors are alike, and each opportunity to design and build a rocket motor is an invaluable learning experience."

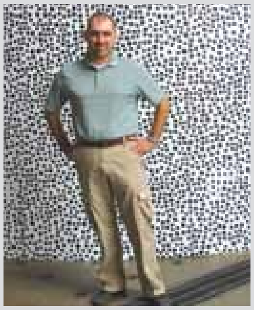
Ben Davis

Dale Jackson

The SRSM development has allowed Mr. Jackson to gain experience by working within design constraints and testing the performance characteristics of different propellant grain configurations. He has expanded his technical contacts to include entities within the Department of Defense. Working with these entities on igniter design has accelerated his knowledge by eliminating unnecessary trial and error methods that he might have encountered without access to these subject matter experts. Mr. Jackson stated, "This type of project is a great way for NASA engineers to get design experience that is usually only obtained by working for a solid rocket motor manufacturer, which is certainly priceless!"

Support of Shell Buckling Testing

George Olden and Jacob Morton have been working at NASA for 3 years and have contributed to the success of the Shell Buckling Knockdown Factor (SBKF) Project through project management, system and test engineering, design support to the test buildup, instrumentation, and testing of the external tank test article #1 (ETTA1) in March 2011. For the ETTA1 test, Mr. Olden served as the assistant test engineer. In addition to his standard duties of managing the design and buildup of test fixtures, test setup, and instrumentation, Mr. Olden's other responsibilities included design of a new control room layout and large-scale setups for emerging technologies such as video image correlation and high-speed cameras. Mr. Olden stated, "Working with the NESC allowed me to get a systems-level perspective of technical challenges facing the Agency and gave me more job satisfaction knowing the work I was doing will fundamentally enhance NASA's structural design process."



George Olden in front of the ETTA1 with photogrammetry target overlay applied.

Mr. Morton is a test technician who supported the SBKF ETTA1 test. Along with the myriad tasks during this size project (e.g., load line installation, instrumentation, test setup), Mr. Morton was responsible for the setup and operation of the high-speed cameras. These cameras were essential in providing details of initial buckling location and propagation within milliseconds of the event. Mr. Morton designed a mounting structure and installed eight cameras at locations around the load test annex to enable 360-degree coverage of the 27.5-foot-diameter by 20-foot-tall test article. Mr. Morton stated, "I have always enjoyed a challenge, and this was the largest high-speed setup we have ever done. We worked many days and very long hours to build up to an absolutely successful test day, and I am proud of that."

Jacob Morton prepares for a lift in front of the ETTA1.

Stennis Space Center

The Stennis Space Center (SSC) provided expert technical support to NESC activities, including the A-3 test stand structural dynamics analysis and AJ-26 engine radiometer measurements in support of the NESC's assessment of Taurus II. SSC has members on several of the NESC's Technical Discipline Teams, and an SSC employee served as an NESC Resident Engineer. The NESC also delivered expertise and assessments that directly benefited SSC projects by providing subject matter materials selection expertise to the High Pressure Industrial Water Piping Infrastructure Replacement Project and delivering a comprehensive structural dynamics analysis of the A-3 test stand. The NESC activities employed the unique capabilities of SSC's Engineering and Test Directorate in support of the A-3 test stand structural dynamics analysis. The A-3 test stand is being designed and built to provide simulated altitude rocket engine tests using a low-pressure test cell which is evacuated by a two-stage steam diffuser/ejector system. During operation, 5,600 pounds/second of steam and rocket exhaust flowing through the diffuser/ejector system and its supersonic discharge to atmosphere will produce a significant vibroacoustic environment in and around the test stand. The NESC was asked to perform an analysis of the structural dynamic response of the stand and its components to the predicted vibroacoustic loading.

13:

SSC employees supporting NESC assessments

Michael D. Smiles

NESC Chief Engineer at SSC

Jody Woods, A-3 Chief Engineer (left), and Dr. Howard Conyers, structural analyst, examine plans for the signal conditioning building, shown in the foreground of the A-3 test stand.

A-3 Test Stand Analysis

Dr. Howard Conyers, structural analyst, conducted vibroacoustic analysis of the ground-level signal conditioning building (SCB) near the base of the A-3 test stand. Collaborating with team members at MSFC, he used ANSYS structural mechanics software to model the SCB and analyze the effects of acoustically induced vibrations. Dr. Conyers also gained valuable exposure to the Nastran finite element modeling software used by the team, learned new techniques for vibration analysis, and was introduced to new intra-Agency contacts. “Working with the NESC showed me that multi-Center cooperation allows us access to Agency-wide expertise not available locally.”

Jody Woods, A-3 Chief Engineer, had multiple roles in the A-3 Test Stand Structural Dynamics Assessment as the assessment requester, team member, and a stakeholder. In his role as team member, he provided design support, loads data, and environmental conditions needed for a successful analysis. As a stakeholder, he was very pleased with the results of the assessment and the depth of the analysis. “The NESC has been a valuable resource to the A-3 Project. We had test stand structural dynamics concerns related to design assumptions that the project could not address, and we looked to the NESC for assistance. The team of experts assembled by the NESC did an outstanding job performing the complex analyses required to address these dynamics issues and allay any concerns,” Mr. Woods stated. This assessment exposed SSC personnel to new modeling software packages and new finite element analysis techniques. “This opportunity has opened the door for SSC to use state-of-the-art software to model and understand difficult problems like these that arise when testing the rocket engines of tomorrow,” Mr. Woods stated.

Subscale Diffuser Assessment

The NESC E-3 Subscale Diffuser Assessment was a great way for Dr. Allgood to apply his extensive exhaust plume diagnostic experience and to learn more about exhaust plume acoustic loads. Subscale diffuser testing was conducted in the SSC E-3 test area to gather data to assist with the A-3 test stand design. Using the data gathered during subscale diffuser testing, he was able to predict the acoustic loads for the full scale test stand. This assessment was his first exposure to the acoustic loading aspect of exhaust plume diagnostics and added depth to his American Institute of Aeronautics and Astronautics (AIAA) paper documenting his analysis. “This project allowed me the chance to learn new techniques for modeling exhaust plume acoustics and to publish an AIAA paper detailing the results.”

Dr. Daniel Allgood investigating acoustic loads on the A-3 test stand.

NESC Honor Award Recipients for 2011

Left to right: Kyong Song, Alliant Techsystems, Inc.; James Reeder, LaRC; Bruce Vu, KSC; Daniel Pruzan, Nielsen Engineering and Research; Louise Strutzenberg, MSFC; Richard Brewer, CSC Applied Technologies; Jay Warren, LaRC; Ben Davis, MSFC; Courtney Flugstad, KSC; Douglas Jones, Jacobs Engineering; Pat Floyd, United Space Alliance; Albert Zimmerman, The Aerospace Corporation; Philip Hattis, Charles Stark Draper Laboratory; Brian Abresch, WFF; Robert Wingate, MSFC; Kurt Severance, LaRC; Daria Topousis, JPL; Thomas Jones, LaRC; Tim Wilson, NESC Deputy Director/presenter; Jeffrey Cerro, LaRC; Ralph Roe, Jr., NESC Director/presenter; Mark Hilburger, LaRC; Patrick Forrester, NESC Chief Astronaut/presenter. Not pictured: Bryan O'Connor, NASA HQ retired; Alden Mackey, Barrios Technology; and William Rose, Rose Engineering and Research, Inc.

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 truths

Bryan O'Connor

In recognition of unwavering advocacy, leadership, and commitment in the formulation and continued successful operation of the NASA Engineering and Safety Center

NESC Leadership Award

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

Alden C. Mackey

In recognition of outstanding technical leadership of NESC assessments and consultations in the loads and dynamics technical area and in support of the Loads and Dynamics Technical Discipline Team

Daniel A. Pruzan

In recognition of exceptional engineering leadership for the NESC's assessment of the Constellation Program Launch Abort Vehicle Stability Augmentation and the Shuttle Carrier Aircraft Phantom Ray Delivery Flight

NESC Engineering Excellence Award

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

Robert B. Davis

In recognition of engineering excellence and outstanding leadership as the technical lead of the highly complex A-3 Test Stand Structural Dynamics Analysis Assessment

Courtney S. Flugstad

In recognition of engineering excellence and outstanding leadership as the Program Manager for the NESC's Shell Buckling Knockdown Factor Project

Philip D. Hattis

In recognition of Guidance, Navigation, and Control engineering excellence for the Impact of Orion Service Module Propellant Slosh on Ares-I Flight Control NESC Assessment

Thomas W. Jones

In recognition of engineering excellence in the successful design, implementation, and operation of the photogrammetry measurement system and center of gravity determination with photogrammetry

William C. Rose

In recognition of engineering excellence in the support of the Boeing Phantom Ray Unmanned Air Vehicle delivery on the NASA Shuttle Carrier Aircraft

Kurt Severance

In recognition of engineering excellence in the development and application of new photogrammetry methods which enabled accurate measurement of the boilerplate Orion crew module trajectory during water entry testing

NESC Engineering Excellence Award
Continued

Louise L. Strutzenberg

In recognition of engineering excellence in computational fluid dynamics modeling and analysis for the Taurus II first stage hot-fire test NESC risk assessment

Bruce T. Vu

In recognition of engineering excellence in plume impingement, acoustics, and thermal modeling for the Taurus II first stage hot-fire NESC risk assessment

Albert H. Zimmerman

In recognition of engineering excellence for innovative battery test development in support of the identification of the Wilkinson Microwave Anisotropy Probe On-Orbit Battery Anomaly

NESC Administrative Excellence Award

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

Daria E. Topousis

In recognition of exceptional and dedicated support to the NASA Technical Fellows in the development and continued enhancement of their NESC Technical Discipline Team Communities of Practice sites on the NASA Engineering Network

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

A-3 Test Stand Structural Dynamics Analysis Team

In recognition of outstanding contributions and innovative approaches to modeling complex structural interfaces with propellant supply systems, steam generation, and diffuser/ejector

Composite Pressure Vessel Life Prediction (Reliability) Model Development Analytical Subteam

In recognition of outstanding contributions in the cross-functional problem solving and methods development for Composite Pressure Vessel Life Prediction Model Development

Crew Module Water Landing Modeling Assessment Team

In recognition of outstanding contributions to the water drop-tests of a full-scale boilerplate crew module on an accelerated schedule

NASA Standard Development for Spaceflight Fastening Systems Team

In recognition of outstanding contributions to NASA and industry collaboration in the development of a NASA standard for threaded fastening systems in spaceflight hardware

NASA Standard for Models and Simulations Recommended Practice Guide Project Team

In recognition of outstanding achievement in the development of a guidebook for the NASA Standard for Models and Simulations

Reinforced Carbon Carbon Fracture Mechanics Analysis Team

In recognition of outstanding fracture mechanics analysis contributions to the understanding of the Reinforced Carbon Carbon Spallation phenomenon

Shell Buckling Knockdown Factor Project Team

In recognition of outstanding achievement in the highly successful test of the 27.5 foot diameter External Tank Test Article 1

Shuttle Carrier Aircraft Aero-Structural Dynamics Team

In recognition of outstanding aero-structural analysis and flight measurements in support of the Boeing Phantom Ray Unmanned Air Vehicle delivery on the NASA Shuttle Carrier Aircraft

Shuttle Processing Mishap Recurring Cause Study Team

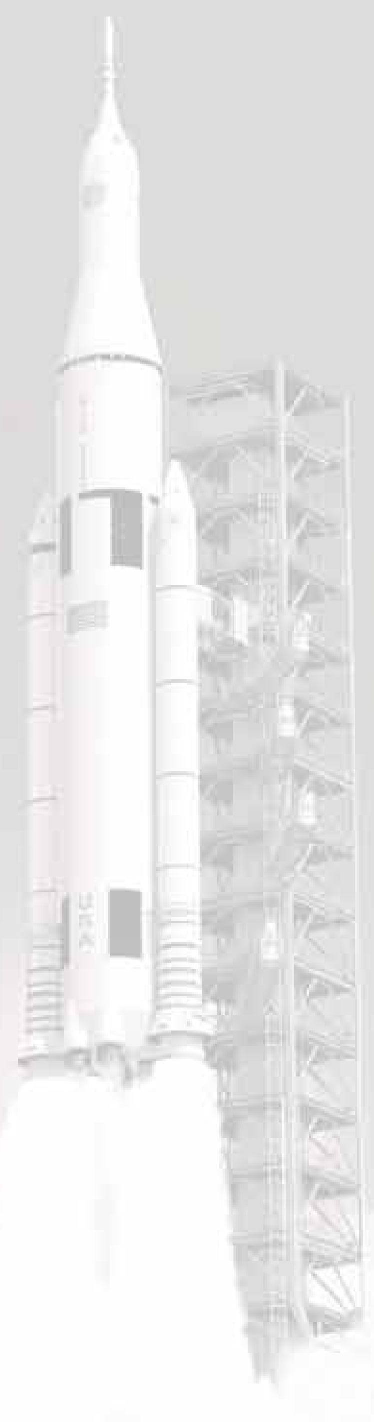
In recognition of outstanding achievement in proactively reducing the risks associated with Shuttle fly-out based on the results of the Shuttle Processing Mishap Recurring Cause Study

Space Shuttle Program External Tank Intertank Stringer Cracking Investigation Team

In recognition of exemplary technical support in the resolution of the Space Shuttle Program External Tank Intertank Stringer Structural Failure

Wilkinson Microwave Anisotropy Probe Battery Operations Problem Resolution Team

In recognition of outstanding contributions in identification of the Wilkinson Microwave Anisotropy Probe On-Orbit Battery Anomaly and crucial support in extending the mission to completion



NASA Team Receives Service to America Medal

NASA\Paul E. Alers

NASA Administrator Charles Bolden, right, presents the National Security and International Affairs Medal to Michael Duncan; J.D. Polk; and Clinton Cragg, NESC Principal Engineer, at left. The three were honored in September at the 2011 Samuel J. Heyman Service to America gala in Washington, D.C., for their contributions to the Chilean miner rescue effort.

Dr. Ivatury S. Raju Receives ICCES Medal

Dr. Ivatury S. Raju, NASA Technical Fellow for Structures, received a Life-Time Achievement Medal from the 2011 International Conference on Computational and Experimental Engineering and Sciences (ICCES) in Nanjing, China, for recognition of his contributions to "Structural Integrity and Durability." This medal is awarded to an individual for sustained and significant contributions in the form of research, teaching, and service to the community, in any area germane to the ICCES series of conferences.

AIAA names Jay Brandon Engineer of the Year

Jay Brandon, a senior research engineer at NASA's Langley Research Center (LaRC), and acting NESC Chief Engineer at LaRC, won the award for his leadership of the Ares I-X Guidance, Navigation, and Control team. The Ares I-X test rocket made a 2-minute powered flight October 28, 2009, and splashed down about 150 miles down range from the Kennedy Space Center — demonstrating that the new, very tall, and thin design could be controlled autonomously. The flight test provided NASA with an enormous amount of data that is being used to improve the design and safety of the next generation of American spaceflight vehicles.

NESC Core Team members

STS-134 Space Shuttle Endeavor docked at the International Space Station

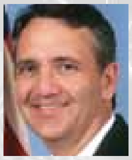
Core Leadership Team

Ralph R. Roe, Jr.

NESC Director

Mr. Ralph R. Roe, Jr. is the NESC's Director at Langley Research Center (LaRC). Mr. Roe has over 28 years of experience in human space flight program management, technical management, and test engineering. Mr. Roe previously held several key positions in the Space Shuttle Program, including Vehicle Engineering Manager, Launch Director, and Kennedy Space Center Engineering Director.

Timmy R. Wilson



NESC Deputy Director

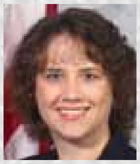
Mr. Timmy R. Wilson is the NESC's Deputy Director at Langley Research Center. Mr. Wilson was formerly the NESC's Chief Engineer at Kennedy Space Center (KSC). Prior to joining the NESC, Mr. Wilson served as Deputy Chief Engineer for Space Shuttle Processing at KSC. Mr. Wilson has over 30 years of engineering and management experience supporting the Space Shuttle Program.

Michael P. Blythe

NESC Deputy Director for Safety

Mr. Michael P. Blythe is the NESC's Deputy Director for Safety and is resident at the Johnson Space Center (JSC). Prior to joining the NESC, Mr. Blythe served as the Acting Assistant Associate Administrator in the Office of the Administrator at NASA Headquarters. Mr. Blythe came to the Office of the Administrator from the Office of Chief Engineer, where he served as the Director for the Engineering and Program/Project Management Division. In this capacity, he was responsible for establishing and implementing Agency engineering and program/project management policy, procedures, and processes to improve the efficiency and success of NASA's investments.

Dawn M. Schaible



Manager, Systems Engineering Office

Ms. Dawn M. Schaible is Manager of the NESC's Systems Engineering Office at Langley Research Center (LaRC). Prior to joining the NESC, Ms. Schaible worked in the International Space Station/Payload Processing Directorate at Kennedy Space Center. Ms. Schaible has over 24 years of experience in systems engineering, integration, and ground processing for the Space Shuttle and International Space Station Programs.

Daniel J. Tenney

Manager, Management and Technical Support Office

Mr. Daniel J. Tenney is Manager of the NESC's Management and Technical Support Office at Langley Research Center (LaRC). Prior to joining the NESC, Mr. Tenney served as the Deputy Chief Financial Officer for Systems at LaRC, where he managed over 30 information systems. Mr. Tenney has 22 years of professional financial, accounting, and systems experience at NASA.

Dr. Daniel Winterhalter

Chief Scientist

Dr. Daniel Winterhalter is the NESC's Chief Scientist and is resident at the Jet Propulsion Laboratory (JPL). Dr. Winterhalter has over 33 years of experience as a research scientist at JPL. His research interests include the spatial evolution of the solar wind into the outer reaches of the heliosphere, as well as its interaction with and influence on planetary environments. In addition, as a member of several flight teams, he has been intimately involved with the planning, launching, and operation of complex spacecraft and space science missions.

Patrick G. Forrester

NESC Chief Astronaut

Mr. Patrick G. Forrester is the NESC's Chief Astronaut and is resident at the Johnson Space Center (JSC). Mr. Forrester began his NASA career in 1993 after serving in the U.S. Army. As a Master Army Aviator he logged over 4800 hours in over 50 different aircraft. He was selected as an astronaut candidate in 1996 and flew on STS-105 (2001), STS-117 (2007), and STS-128 (2009). He has logged over 950 hours in space, including four spacewalks totaling 25 hours and 22 minutes of EVA time.

NASA Headquarters Liaison

Wayne R. Frazier

NASA Headquarters Senior SMA Integration Manager

Mr. Wayne R. Frazier currently serves as Senior Safety and Mission Assurance Manager in the Office of Safety and Mission Assurance (OSMA), where he is assigned as the Liaison Officer to the NESC, the Office of the Chief Engineer, the Software Independent Verification and Validation Facility in West Virginia, and other remote activities of OSMA. He was formerly Manager of System Safety in the OSMA at NASA Headquarters and has over 36 years of experience in System Safety, Propulsion and Explosive Safety, Mishap Investigation, Range Safety, Pressure Systems, Crane Safety and Orbital Debris Mitigation.

NESC Principal Engineers

Clinton H. Cragg

NESC Principal Engineer

Mr. Clinton H. Cragg is a Principal Engineer with the NESC at Langley Research Center (LaRC). Mr. Cragg came to the NESC after retiring from the U.S. Navy. Mr. Cragg served as the Commanding Officer of the U.S.S. Ohio and later as the Chief of Current Operations, U.S. European Command. Mr. Cragg has over 33 years of experience in supervision, command, and ship-borne nuclear safety.

Dr. Michael G. Gilbert

NESC Principal Engineer

Dr. Michael G. Gilbert is a Principal Engineer with the NESC at Langley Research Center (LaRC). Dr. Gilbert was formerly the NESC Chief Engineer at LaRC. Before joining the NESC, he was Head of the LaRC Systems Management Office. Dr. Gilbert has over 33 years of engineering, research, and management experience with aircraft, missile, spacecraft, Space Shuttle, and International Space Station Programs.

Michael T. Kirsch

NESC Principal Engineer

Mr. Michael T. Kirsch is a Principal Engineer with the NESC at Langley Research Center (LaRC). Mr. Kirsch joined the NESC from the NASA's White Sands Test Facility (WSTF), where he served as the Deputy Manager responsible for planning and directing developmental and operational tests of spacecraft propulsion systems and related subsystems. Mr. Kirsch has over 22 years of experience in managing projects and test facilities.

NESC Chief Engineers

Jay Brandon

NESC Chief Engineer (Acting)

Mr. Jay Brandon is Acting NESC Chief Engineer at Langley Research Center (LaRC). He most recently served as the Guidance, Navigation, and Controls lead for the Ares I-X. Mr. Brandon has over 27 years of experience in flight dynamics performing wind tunnel testing and piloted simulation and flight testing primarily of high-performance airplanes.

Dr. Nancy J. Currie

NESC Chief Engineer

Dr. Nancy J. Currie is the NESC's Chief Engineer at Johnson Space Center (JSC). Dr. Currie came to the NESC from JSC, where she served as the Deputy Director of the Engineering Directorate. Dr. Currie has over 23 years of experience in robotics and human factors engineering. Selected as an astronaut in 1990, Dr. Currie is a veteran of four space shuttle missions and has accrued 1000 hours in space.

NESC Chief Engineers *Continued*

Dr. John H. Day

NESC Chief Engineer (Acting)

Dr. John H. Day is Acting NESC Chief Engineer at Goddard Space Flight Center (GSFC). Dr. Day was formerly Chief of the Electrical Engineering Division at GSFC. Dr. Day has over 29 years of experience in space power and electrical systems and in leading flight hardware development activities for over 16 robotic science missions. Dr. Day has also served as Chief Technologist for GSFC's Engineering and Technology Directorate.

Dawn C. Emerson

NESC Chief Engineer

Ms. Dawn C. Emerson is the NESC's Chief Engineer at Glenn Research Center (GRC). Ms. Emerson came to the NESC from GRC, where she most recently served as the Deputy Project Manager during formulation of the Solar Electric Propulsion Flight Demonstration Project. Ms. Emerson has over 26 years of management and technical experience with NASA and private industry.

Walter C. Engelund

NESC Chief Engineer

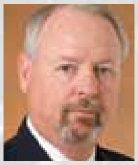
Mr. Walter C. Engelund is the NESC's Chief Engineer at Langley Research Center (LaRC). Mr. Engelund came to the NESC from LaRC, where he served as the Head of the Atmospheric Flight and Entry Systems Branch. Mr. Engelund has over 22 years of experience as a recognized expert in launch and entry vehicle aerodynamics, atmospheric flight dynamics, and hypersonic flight systems.

Steven J. Gentz

NESC Chief Engineer

Mr. Steven J. Gentz is the NESC's Chief Engineer at Marshall Space Flight Center (MSFC). Mr. Gentz was formerly a Principal Engineer with the NESC at Langley Research Center (LaRC). Mr. Gentz has over 28 years of experience involving numerous NASA, Department of Defense, and industry failure analyses and incident investigations, including Challenger, Columbia, Tethered Satellite System, and the TWA 800 Accident Investigations.

R. Lloyd Keith



NESC Chief Engineer

Mr. R. Lloyd Keith is the NESC's Chief Engineer, as well as support and backup for the Center Chief Engineer at the Jet Propulsion Laboratory (JPL). Mr. Keith has over 34 years of experience working in both technical and managerial positions. Mr. Keith has supported a number of flight projects, including the Mars Pathfinder Project, SeaWinds, Stardust, Mars '98, New Millennium Deep Space 1, and the Flight Hardware Logistics Program.

Nans Kunz

NESC Chief Engineer

Mr. Nans Kunz is the NESC's Chief Engineer at Ames Research Center (ARC). Mr. Kunz came to the NESC from the Systems Engineering Division at ARC. Mr. Kunz has over 33 years of engineering experience leading and managing NASA programs and projects, including serving as the Chief Engineer of the Stratospheric Observatory For Infrared Astronomy (SOFIA) Project.

NESC Chief Engineers *Continued*

Stephen A. Minute

NESC Chief Engineer

Mr. Stephen A. Minute is the NESC's Chief Engineer at Kennedy Space Center (KSC). Mr. Minute came to the NESC from KSC, where he served as the Chief of the Space Shuttle Safety, Quality, and Mission Assurance Division. Mr. Minute has over 27 years of engineering and management experience in the Space Shuttle and International Space Station Programs.

Michael D. Smiles

NESC Chief Engineer

Mr. Michael D. Smiles is the NESC's Chief Engineer at Stennis Space Center (SSC). Mr. Smiles joined the NESC from SSC, where he served as the Safety and Mission Assurance (S&MA) Manager. Mr. Smiles has over 26 years of management and technical experience with NASA at SSC and Marshall Space Flight Center.

Dr. James F. Stewart

NESC Chief Engineer

Dr. James F. Stewart is the NESC's Chief Engineer at Dryden Flight Research Center (DFRC). Dr. Stewart joined the NESC from DFRC, where he served as the Dryden Exploration Mission Director. Dr. Stewart has over 45 years of management and technical experience leading missile and aircraft programs.

Timothy G. Trenkle

NESC Chief Engineer

Mr. Timothy G. Trenkle is the NESC's Chief Engineer at Goddard Space Flight Center (GSFC). Mr. Trenkle joined the NESC from GSFC, where he has over 19 years of technical experience serving as the technical lead for a number of flight programs and technical assignments, including serving as the Chief Engineer for the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP).

NASA Technical Fellows

Michael L. Aguilar

NASA Technical Fellow

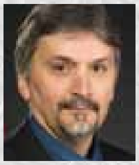
Mr. Michael L. Aguilar is the NASA Technical Fellow for Software and is resident at Goddard Space Flight Center (GSFC). Mr. Aguilar joined the NESC from GSFC, where he served as the James Webb Space Telescope (JWST) Instrument Software Manager. Mr. Aguilar has over 35 years of experience on embedded software development.

Cornelius J. Dennehy

NASA Technical Fellow

Mr. Cornelius J. Dennehy is the NASA Technical Fellow for Guidance, Navigation, and Control (GNC) and is resident at Goddard Space Flight Center (GSFC). Mr. Dennehy came to the NESC from the Mission Engineering and Systems Analysis Division at GSFC, where he served as the Division's Assistant Chief for Technology. Mr. Dennehy has over 31 years of experience in the architecture, design, development, integration, and operation of GNC systems, and space platforms for communications, defense, remote sensing, and scientific mission applications.

Roberto Garcia



NASA Technical Fellow

Mr. Roberto Garcia is the NASA Technical Fellow for Propulsion and is resident at Marshall Space Flight Center (MSFC). Mr. Garcia came to the NESC from the Solid Propulsion Systems Division, where he served as Division Chief. Mr. Garcia has over 20 years of experience in performing aerodynamic, hydrodynamic, and engine system design and analysis of rocket propulsion.

NASA Technical Fellows *Continued*

Oscar Gonzalez

NASA Technical Fellow

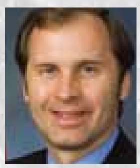
Mr. Oscar Gonzalez is the NASA Technical Fellow for Avionics and is resident at Goddard Space Flight Center (GSFC). Mr. Gonzalez came to the NESC from GSFC, where he served as the International Space Station/Express Logistic Carrier (ELC) Avionics Systems Manager. Mr. Gonzalez has over 33 years of NASA and private industry experience where he has held a variety of critical leadership roles in power electronics, electrical systems, instrument systems, and avionics systems.

Denney J. Keys

NASA Technical Fellow

Mr. Denney J. Keys is the NASA Technical Fellow for Electrical Power and is resident at Goddard Space Flight Center (GSFC). Mr. Keys served as the Lead Power Systems Engineer in the Power Systems Branch at GSFC before joining the NESC. Mr. Keys has over 31 years of private industry and NASA experience with electrical power systems.

Dr. Curtis E. Larsen



NASA Technical Fellow

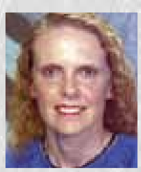
Dr. Curtis E. Larsen is the NASA Technical Fellow for Loads and Dynamics and is resident at Johnson Space Center (JSC). Prior to joining the NESC, Dr. Larsen was the Technical Discipline Manager for Cargo Integration Structures in the Space Shuttle Program's Flight Operations and Integration Office. Dr. Larsen has over 31 years of engineering experience with expertise in stochastic structural dynamics, structural safety, and probabilistic engineering applications.

Daniel G. Murri

NASA Technical Fellow

Mr. Daniel G. Murri is the NASA Technical Fellow for Flight Mechanics and is resident at Langley Research Center (LaRC). Mr. Murri served as Head of the Flight Dynamics Branch at LaRC before joining the NESC. He has over 30 years of engineering experience conducting numerous wind-tunnel, simulation, flight-test, and theoretical studies in the exploration of new technology concepts and in support of aircraft development programs.

Dr. Cynthia H. Null



NASA Technical Fellow

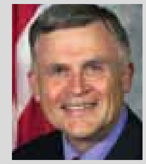
Dr. Cynthia H. Null is the NASA Technical Fellow for Human Factors and is resident at Ames Research Center (ARC). Before joining the NESC, Dr. Null was a scientist in the Human Factors Division and Deputy Program Manager of the Space Human Factors Engineering Project. Dr. Null has 25 years of experience lecturing on Human Factors, and another 19 years of experience in Human Factors applied to NASA programs.

Joseph W. Pellicciotti

NASA Technical Fellow

Mr. Joseph W. Pellicciotti is the NASA Technical Fellow for Mechanical Systems and is resident at Goddard Space Flight Center (GSFC). Mr. Pellicciotti served as the Chief Engineer for the GSFC Mechanical Systems Division before joining the NESC. Mr. Pellicciotti has over 23 years of combined private industry and NASA experience designing structure and mechanisms for commercial, military, and civil spacecraft.

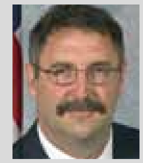
Dr. Robert S. Piascik



NASA Technical Fellow

Dr. Robert S. Piascik is the NASA Technical Fellow for Materials and is resident at Langley Research Center (LaRC). Dr. Piascik joined the NESC from the LaRC Mechanics of Materials Branch and the Metals and Thermal Structures Branch, where he served as a Senior Materials Scientist. Dr. Piascik has over 27 years experience in the commercial nuclear power industry and over 18 years of experience in basic and applied materials research for several NASA programs.

Dr. William H. Prosser



NASA Technical Fellow

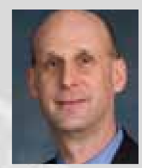
Dr. William H. Prosser is the NASA Technical Fellow for Nondestructive Evaluation and is resident at Langley Research Center (LaRC). Dr. Prosser joined the NESC from the Nondestructive Evaluation Sciences Branch at LaRC. Dr. Prosser has over 24 years of experience in the field of ultrasonic and acoustic emission sensing techniques.

Dr. Ivatury S. Raju

NASA Technical Fellow

Dr. Ivatury S. Raju is the NASA Technical Fellow for Structures and is resident at Langley Research Center (LaRC). Dr. Raju was the Senior Technologist in the LaRC Structures and Materials Competency prior to joining the NESC. Dr. Raju has over 36 years of experience in structures, structural mechanics, and structural integrity.

Steven L. Rickman



NASA Technical Fellow

Mr. Steven L. Rickman is the NASA Technical Fellow for Passive Thermal and is resident at Johnson Space Center (JSC). Mr. Rickman joined the NESC from JSC's Thermal Design Branch, where he served as the Chief. Mr. Rickman has over 26 years of management and technical experience in passive thermal control.

Henry A. Rotter

NASA Technical Fellow

Mr. Henry (Hank) A. Rotter is the NASA Technical Fellow for Life Support/Active Thermal and is resident at Johnson Space Center (JSC). Mr. Rotter joined the NESC from the JSC Crew and Thermal Systems Division and the Space Launch Initiative Program, where he was Engineering Manager and the Orbital Space Plane Team Leader for life support and active thermal control teams. Mr. Rotter has over 44 years of life support and active thermal control systems experience during the Apollo, Space Shuttle, and Orbital Space Plane Programs.

Dr. David M. Schuster

NASA Technical Fellow

Dr. David M. Schuster is the NASA Technical Fellow for Aerosciences and is resident at Langley Research Center (LaRC). Prior to joining the NESC, Dr. Schuster was the Branch Head for the Structural and Thermal Systems Branch in the Systems Engineering Directorate. Dr. Schuster has over 33 years of experience in the aerospace industry with expertise in aeroelasticity and integrated aerodynamic analysis.

Frank H. Bauer
NESC Discipline Expert for Guidance Navigation and Control (2003–04) Left the NESC to become the Exploration Systems Mission Directorate Chief Engineer at NASA HQ and has since retired

J. Larry Crawford
NESC Deputy Director for Safety (2003–04) Left the NESC to become Director of Safety and Mission Assurance at the Kennedy Space Center (KSC) and has since retired

Dr. Charles J. Camarda
NESC Deputy Director for Advanced Projects (2006–09) Left the NESC to become Senior Advisor for Innovation in the Office of the Chief Engineer at NASA Headquarters

Kenneth D. Cameron
NESC Deputy Director for Safety (2005–08) Left the NESC to accept a position with Northrop Grumman

Steven F. Cash
NESC Chief Engineer at Marshall Space Flight Center (MSFC) (2005) Left the NESC to become the Manager, Shuttle Propulsion Office at MSFC

Derrick J. Cheston
NESC Chief Engineer at Glenn Research Center (GRC) (2003–07) Left the NESC to participate in the Senior Executive Service Candidate Development Program (SESCDP) and then returned to GRC as the Chief of the Mechanical and Fluid Systems Division

Mitchell L. Davis
NASA Technical Fellow for Avionics (2007–09) Left the NESC to become the Chief Avionics Systems Engineer in the Electrical Engineering Division at Goddard Space Flight Center

Dennis B. Dillman
NESC Chief Engineer at NASA Headquarters (HQ) (2005–08) Left the NESC to become an Engineer in the Science Mission Directorate at NASA HQ

Freddie Douglas, III
NESC Chief Engineer at Stennis Space Center (SSC) (2007–08) Left the NESC to become Manager, Office of Safety and Mission Assurance at SSC

Patricia L. Dunnington
Manager, Management and Technical Support Office (2006–08) Retired

Dr. Michael S. Freeman
NESC Chief Engineer at Ames Research Center (2003–04) Retired

T. Randy Galloway
NESC Chief Engineer at Stennis Space Center (SSC) (2003–04) Currently the Director of the Engineering and Test Directorate at SSC

Dr. Edward R. Generazio
NESC Discipline Expert for Nondestructive Evaluation (2003–05) Left the NESC to become a Senior Research Engineer, Research Directorate, Langley Research Center

Dr. Richard J. Gilbrech
NESC Deputy Director (2003–05) Currently the Deputy Center Director at Stennis Space Center

Michael Hagopian
NESC Chief Engineer at Goddard Space Flight Center (GSFC) (2003–07) Left the NESC to become the Chief Engineer in the Engineering Directorate at GSFC

David A. Hamilton
NESC Chief Engineer at Johnson Space Center (2003–07) Retired

Dr. Charles E. Harris
NESC Principal Engineer (2003–06) Currently the Director, Research Directorate, Langley Research Center

Dr. Steven A. Hawley
NESC Chief Astronaut (2003–04) Left the NESC to become the Director of Astromaterials Research and Exploration Science at Johnson Space Center and has since retired

Marc S. Hollander
Manager, Management and Technical Support Office (2005–06) Left the NESC to accept a position as the Associate Director for Management, National Institutes of Health

George D. Hopson
NASA Technical Fellow for Propulsion (2003–07) Retired

Keith L. Hudkins
NASA Headquarters Office of the Chief Engineer Representative (2003–07) Retired

Danny D. Johnston
NESC Chief Engineer at Marshall Space Flight Center (MSFC) (2003–04) Left the NESC to work a detailed assignment at MSFC in the NASA Chief Engineer's Office and has since retired

Michael W. Kehoe
NESC Chief Engineer at Dryden Flight Research Center (DFRC) (2003–05) Left the NESC to become the DFRC Liaison in the Crew Exploration Vehicle Flight Test Office at Johnson Space Center and has since retired

Robert A. Kichak
NESC Discipline Expert for Power and Avionics (2003–07) Retired

Dr. Dean A. Kontinos
NESC Chief Engineer at Ames Research Center (ARC) (2006–07) Left the NESC to work a detailed assignment as the Technical Integration Manager of the Fundamental Aeronautics Program in the Aeronautics Research Mission Directorate at NASA HQ and has since returned to ARC in the Office of the Chief Engineer

Julie A. Kramer White
NESC Discipline Expert for Mechanical Analysis (2003–06) Currently the Chief Engineer, Multi-Purpose Crew Vehicle Program at Johnson Space Center

Steven G. Labbe
NESC Discipline Expert for Flight Sciences (2003–06) Currently the Chief, Aeroscience and Flight Mechanics Division at Johnson Space Center

Matthew R. Landano
NESC Chief Engineer at NASA's Jet Propulsion Laboratory (JPL) (2003–04) Returned to his assignment at JPL as the Director of Office of Safety and Mission Success

David S. Leckrone
NESC Chief Scientist (2003–06) Left the NESC to become the Senior Project Scientist for the Hubble Space Telescope at Goddard Space Flight Center and has since retired

Richard T. Manella
NESC Chief Engineer at NASA's Glenn Research Center (GRC) (2009–10) Left the NESC to become Glenn Research Center's Chief Engineer

John P. McManamen
NASA Technical Fellow for Mechanical Systems (2003–07) Currently the Deputy Manager, White Sands Test Facility

Brian K. Muirhead
NESC Chief Engineer at NASA's Jet Propulsion Laboratory (JPL) (2005–07) Returned to his assignment as the Chief Engineer, Jet Propulsion Laboratory

Dr. Paul M. Munafo
NESC Deputy Director (2003–04) Left the NESC to become the Assistant Director for Safety and Engineering at Marshall Space Flight Center (MSFC) and has since retired

Stan C. Newberry
Manager of the NESC's Management and Technical Support Office (2003–04) Left the NESC to become the Deputy Center Director at Ames Research Center and has since left NASA to accept a position at DoD

Dr. Tina L. Panontin
NESC Chief Engineer at Ames Research Center (2008–09) Returned to her assignment as the Ames Research Center Chief Engineer

Dr. Shamim A. Rahman
NESC Chief Engineer at Stennis Space Center (SSC) (2005–06) Left the NESC to become the Deputy Director of the Engineering and Test Directorate at SSC

Jerry L. Ross
NESC Chief Astronaut (2004–06) Returned to his assignment as Chief of the Vehicle Integration Test Office at Johnson Space Center

Dr. Charles F. Schafer
NESC Chief Engineer at Marshall Space Flight Center (2006–10) Retired

Steven S. Scott
NESC Chief Engineer at Goddard Space Flight Center (2008–09) NESC Discipline Expert (now called NASA Technical Fellow) for Software (2003–05) Returned to his assignment as the Goddard Space Flight Center Chief Engineer

Bryan K. Smith
NESC Chief Engineer at Glenn Research Center (2008–10) Left the NESC to serve as Chief of the Systems Engineering and Systems Analysis Division at Glenn Research Center

John E. Tinsley
NASA Headquarters Senior Safety and Mission Assurance Manager for NESC (2003–04) Left the NESC to become the Director of the Mission Support Division at NASA Headquarters and has since left NASA to accept a position with Northrop Grumman

Clayton P. Turner
NESC Chief Engineer at Langley Research Center (2008–09) Returned to his assignment as the Langley Research Center Chief Engineer

NESC/NASA Published Technical Memoranda

1. Ares-I Upper Stage Design Study: The Effects of Buckling Knockdown Factors and Internal Pressure NASA/TM-2010-216848
2. Static Buckling Tests of Aerospace Vehicle Structures NASA/TM-2010-216849
3. Shell Buckling Knockdown Factor 1st Annual Workshop 14-15 October, 2009 Summary of Proceedings NASA/TM-2010-216850
4. Design of Orthogrid Cylinder Test Articles For the Shell Buckling Knockdown Factor Assessment NASA/TM-2010-216866 ARL-TR-5122
5. Comparison of Requirements for Composite Structures for Aircraft and Space Applications NASA/TM-2010-216869
6. Pre-Test Analysis Predictions for the Shell Buckling Knockdown Factor Checkout Tests TA01 and TA02 .... NASA/TM-2011-216875 ARL-TR-5123
7. Longitudinal Weld Land Buckling in Compression-Loaded Orthogrid Cylinders NASA/TM-2010-216876 ARL-TR-5121
8. Guidance, Navigation & Control (GN&C) Design Overview and Flight Test Results From NASAs Max Launch Abort System (MLAS) NASA/TM-2010-216877
9. Fracture Mechanics Analyses of the Slip-Side Joggle Regions of Wing-Leading-Edge Panels NASA/TM-2011-216878
10. Probabilistic Design Case Study - NASA Engineering and Safety Center (NESC) Composite Crew Module (CCM) ...... NASA/TM-2011-217042/Volume I
11. Probabilistic Design Case Study - NASA Engineering and Safety Center (NESC) Composite Crew Module (CCM) - Appendices .... NASA/TM-2011-217042/Volume II
12. Peer Review of Launch Environments NASA/TM-2011-217043
13. Lightweight Installable Micrometeoroid and Orbital Debris (MMOD) Shield Concepts for International Space Station (ISS) Modules .... NASA/TM-2011-217044/Volume I
14. Lightweight Installable Micrometeoroid and Orbital Debris (MMOD) Shield Concepts for International Space Station (ISS) Modules - Appendices .... NASA/TM-2011-217044/Volume II
15. Ares-V Design Study: The Effects of Buckling Knockdown Factors, Internal Pressure, and Materials NASA/TM-2011-217061
16. In-Suit Light Exercise (ISLE) Prebreathe Protocol Peer Review Assessment. .... NASA/TM-2011-217062/Volume I
17. In-Suit Light Exercise (ISLE) Prebreathe Protocol Peer Review Assessment - Appendices .... NASA/TM-2011-217062/Volume II
18. Simulation Framework for Rapid Entry, Descent, and Landing (EDL) Analysis, Phase 2 Results NASA/TM-2011-217063
19. International Space Station (ISS) Solar Array Wing (SAW) Lessons Learned .... NASA/TM-2011-217064/Volume I
20. International Space Station (ISS) Solar Array Wing (SAW) Lessons Learned - Appendices .... NASA/TM-2011-217064/Volume II
21. Performance Characterization of Loctite 242 and 271 Liquid Locking Compounds (LLCs) as a Secondary Locking Feature for International Space Station (ISS) Fasteners NASA/TM-2011-217068
22. Independent Review of U.S. and Russian Probabilistic Risk Assessments for the International Space Station Mini Research Module #2 Micrometeoroid and Orbital Debris Risk NASA/TM-2011-217070
23. Recommendations for Safe Separation Distances From the Kennedy Space Center (KSC) Vehicle Assembly Building (VAB) Using a Heat-Flux-Based Analytical Approach - Abridged NASA/TM-2011-217071
24. Space Shuttle Program (SSP) Orbiter Main Propulsion System (MPS) Gaseous Hydrogen (GH2) Flow Control Valve (FCV) Poppet Eddy Current (EC) Inspection Probability of Detection (POD) Study .... NASA/TM-2011-217072/Volume I
25. Space Shuttle Program (SSP) Orbiter Main Propulsion System (MPS) Gaseous Hydrogen (GH2) Flow Control Valve (FCV) Poppet Eddy Current (EC) Inspection Probability of Detection (POD) Study - Appendices .... NASA/TM-2011-217072/Volume II
26. Pre-Test Analysis for 45-Percent-Scale Ares-I Liquid Hydrogen Barrel Test Articles NASA/TM-2011-217073 ARL-TR-5486
27. Design of the Space Shuttle External-Tank-Derived Test Articles for the Shell Buckling Knockdown Factor Project NASA/TM-2011-217074 ARL-TR-5485
28. Independent Review of the Constellation Program (CxP) Ares-I Launch Vehicle Control Sensitivity to Orion Service Module (SM) Tank Slosh Dynamics NASA/TM-2011-217075
29. Recent Experiences of the NASA Engineering and Safety Center (NESC) Guidance Navigation and Control (GN&C) Technical Discipline Team (TDT) NASA/TM-2011-217083
30. Flight Simulation Model Exchange .... NASA/TM-2011-217085/Volume I
31. Flight Simulation Model Exchange - Appendices .... NASA/TM-2011-217085/Volume II
32. Max Launch Abort System (MLAS) Landing Parachute Demonstrator (LPD) Drop Test NASA/TM-2011-217086
33. A Summary of the Rendezvous, Proximity Operations, Docking, and Undocking (RPODU) Lessons Learned from the Defense Advanced Research Project Agency (DARPA) Orbital Express (OE) Demonstration System Mission NASA/TM-2011-217088
34. Readiness for First Crewed Flight NASA/TM-2011-217089
35. Development and Certification of Ultrasonic Background Noise Test (UBNT) System for use on the International Space Station (ISS) NASA/TM-2011-217151
36. Orion Alternate Launch Abort System (ALAS) Follow On Technical Investigations Assessment .... NASA/TM-2011-217155/Volume I
37. Orion Alternate Launch Abort System (ALAS) Follow On Technical Investigations Assessment - Appendices .... NASA/TM-2011-217155/Volume II
38. A-3 Test Stand Structural Dynamics Analysis NASA/TM-2011-217160
39. Assessment of Fatigue-Based Reliability Computations for Space Shuttle Program (SSP) Solid Rocket Booster (SRB) Integrated Electronic Assembly (IEA) Power Buss Isolation Supply (PBIS) Transformers NASA/TM-2011-217165
40. Structural Assessment of the International Space Station (ISS) European-Manufactured Modules .... NASA/TM-2011-217172/Volume I
41. Assessment of NASA's Approach to Space Transportation System (STS)-135 With Soyuz Crew Rescue NASA/TM-2011-217175

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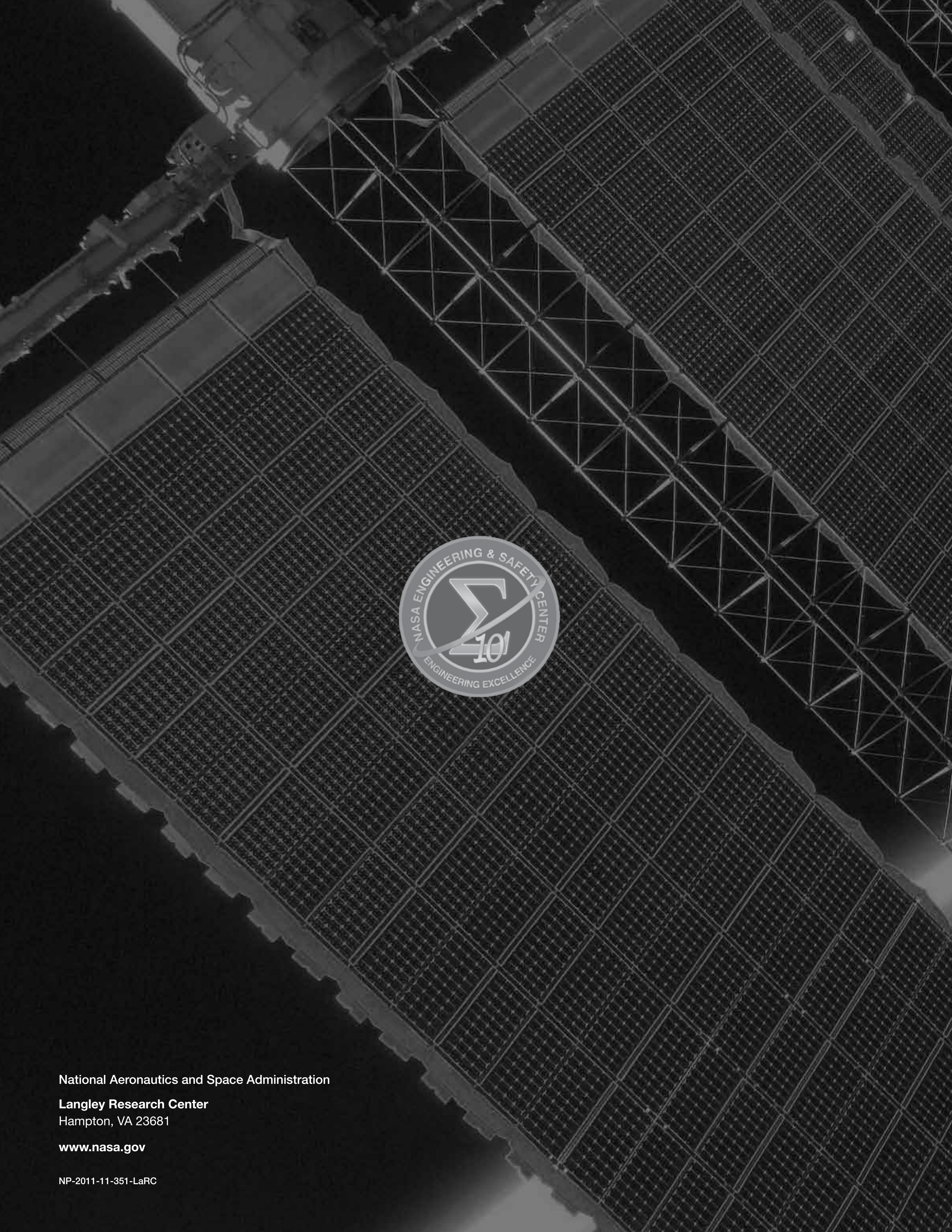
NESC/NASA Published Technical Memoranda *... continued*

Presented Papers

1. The First Flight Decision for New Human Spacecraft Vehicles - A General Approach. Presented at 62nd International Astronautical Congress, October 3-7, 2011, Cape Town, South Africa.
2. Modeling, Analysis and Simulation Approaches Used in Development of the National Aeronautics and Space Administration Max Launch Abort System. Presented at 26th Aerospace Testing Seminar, March 29-31, 2011, Manhattan Beach, California.
3. A Review of the NASA MLAS Flight Demonstration. Presented at 21st AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, May 23-26, 2011, Dublin, Ireland.
4. Testing Strategies and Methodologies for the Max Launch Abort System. Presented at 26th Aerospace Testing Seminar, March 29-31, 2011, Manhattan Beach, California.
5. Overview of the NESC Passive Thermal Technical Discipline Team. Presented at 2011 Thermal and Fluids Analysis Workshop, August 15-19, 2011, Newport News, Virginia.
6. Introduction to On-Orbit Thermal Environments. Presented at 2011 Thermal and Fluids Analysis Workshop, August 15-19, 2011, Newport News, Virginia.
7. Ensuring Durability and Damage Tolerance in Aerospace Structures. Presented at ICCES '11 - International Conference on Computational and Experimental Engineering and Sciences, April 18-21, 2011, Nanjing, China.
8. An Improved Method of Structural-Borne Random Vibration Mass Attenuation. Presented at 162nd Meeting of the Acoustical Society of America, October 31-November 4, 2011, San Diego, California.
9. Special Topics in Random Vibrations. Presented at Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 7-9, 2011, El Segundo, California.
10. The NASA Engineering and Safety Center (NESC): Shock and Vibration Training Program. Presented at Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 7-9, 2011, El Segundo, California.
11. Wilkinson Microwave Anisotropy Probe (WMAP) Nickel-Hydrogen (NiH2) Battery Anomaly Investigation. Presented at 29th Annual Space Power Workshop, April 18-21, 2011, Los Angeles, California.
12. Progress in Quantifying Uncertainty for Vibroacoustic Environments. Presented at Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 7-9, 2011, El Segundo, California.
13. Spacecraft Testing Programs: Adding Value to the Systems Engineering Process. Presented at 26th Aerospace Testing Seminar, March 29-31, 2011, Manhattan Beach, California.
14. Hutchings, A.; Shah, P.; Streett, C. L.; and Larsen, C. E.: Validation of Methods to Predict Vibration of a Panel in the Near Field of a Hot Supersonic Rocket Plume. Presented at 17th AIAA/CEAS Aeroacoustics Conference, June 6-8, 2011, Portland, Oregon.
15. Hutchings, A.; and Shah, P.: Validation of Methods to Predict Vibration of a Panel in the Near Field of a Hot Supersonic Rocket Plume. Presented at Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 7-9, 2011, El Segundo, California.
16. Estimating Modal Damping From Operational Tests. Presented at Spacecraft and Launch Vehicle Dynamic Environment Workshop, June 7-9, 2011, El Segundo, California.
17. Human Factors Throughout the Life Cycle: Lessons Learned From the Shuttle Program. 5th International Association for the Advancement of Space Safety Conference, October 17-19, 2011, Versailles, France.
18. Human Factors Throughout the Life Cycle: Lessons Learned From the Shuttle Program - Manufacturing. 5th International Association for the Advancement of Space Safety Conference, October 17-19, 2011, Versailles, France.
19. Grid Fin Stabilization of the Orion Launch Abort Vehicle. 29th AIAA Applied Aerodynamics Conference, June 27-30, 2011, Honolulu, Hawaii.
20. High-Order Methods in NASA's Next Generation of Computational Fluid Dynamics Tools. European Workshop on High Order Numerical Methods for Evolutionary PDEs: Theory and Applications, April 11-15, 2011, Trento, Italy.

The NESC is proud to have provided support to 21 Space Shuttle missions since STS-114 Return to Flight. We salute the men and women of the Space Shuttle Program for 30 years of dedication and achievement.



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