National Aeronautics and Space Administration

NESC

NASA ENGINEERING & SAFETY CENTER

2010

TECHNICAL UPDATE

wwww.nasa.gov

The NASA Engineering and Safety Center Team in 2010

Welcome to the NASA Engineering and Safety Center

The members of the NASA Engineering and Safety Center (NESC) are pleased to present our 2010 NESC Technical Update. The primary goal of the NESC is to provide the engineering data and recommendations needed for NASA Centers and Missions Directorates to make better informed decisions. To accomplish this goal, the NESC relies on our Agency-wide, diverse, multi-generation teams to enable robust, timely and innovative solutions to NASA's tough technical problems. It is our team members, especially the hundreds of matrixed personnel, who are the true strength of the NESC. We are very proud to highlight again this year the outstanding contributions to the Agency of our broad-based teams.

The NESC continued to focus on providing real-time problem solving for the Space Shuttle and International Space Station Programs, with particular attention on the Space Shuttle as it flies out its remaining missions. We continued to actively support numerous critical robotic spacecraft missions, including Mars Science Laboratory and the James Webb Space Telescope. The NESC completed several significant testing milestones as part of our assessments this year. The composite crew module completed full-scale testing at the Langley Research Center and the first drop test of the crew module water landing modeling assessment was conducted at the U.S. Army Test Center. The NESC also actively engaged in a number of study teams exploring options for the future of human spaceflight exploration.

This year the NESC's contributions reached beyond NASA. We applied our technical expertise to help address critical national and international issues. The NESC supported the Department of Transportation by providing electrical, software and systems engineering expertise in their investigation of unintended accelerations on certain automobile models. NASA and the NESC were also called into action to support the care and rescue of the 33 trapped miners in Chile.

Sharing our collective expertise and the lessons learned from our activities is important to the NESC and NASA as a whole, and we continue to look for new ways to communicate across the Agency and with our stakeholders. This publication includes many of our broadly applicable lessons learned and illustrates the collaborative model that has enabled us to be successful. As NASA prepares for the next phase of exploration, the NESC will continue to evolve to meet the needs of the Agency, while remaining committed to the premise on which we were founded — engineering excellence.

The NESC performed a review and assessment of structural dynamics due to the vibroacoustic environment predicted during operation of the A-3 test stand when testing large-thrust, liquid-fueled engines. Illustration of the A-3 Test Stand under construction at Stennis Space Center.

"In these changing times, it is comforting to know that there is a NASA organization, the NESC, that can perform in-depth technical reviews and provide engineering advice based solely on the technical merits of the case. This year I will continue to rely on the NESC's advice even more, as we face challenges to safely retire the Space Shuttle, and to facilitate development of a safe commercial human spaceflight transportation system."

— Bryan D. O'Connor
NASA Chief Safety and Mission Assurance Officer

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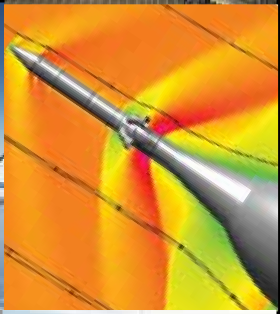
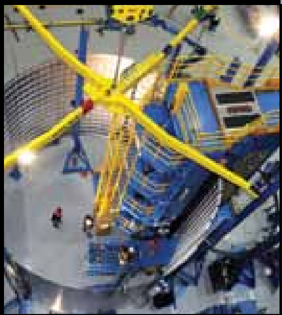



The NESC Review Board (NRB) holds weekly video conferences to peer review and approve all NESC technical assessments and reports. All technical decisions made by the NESC are products of the NRB.

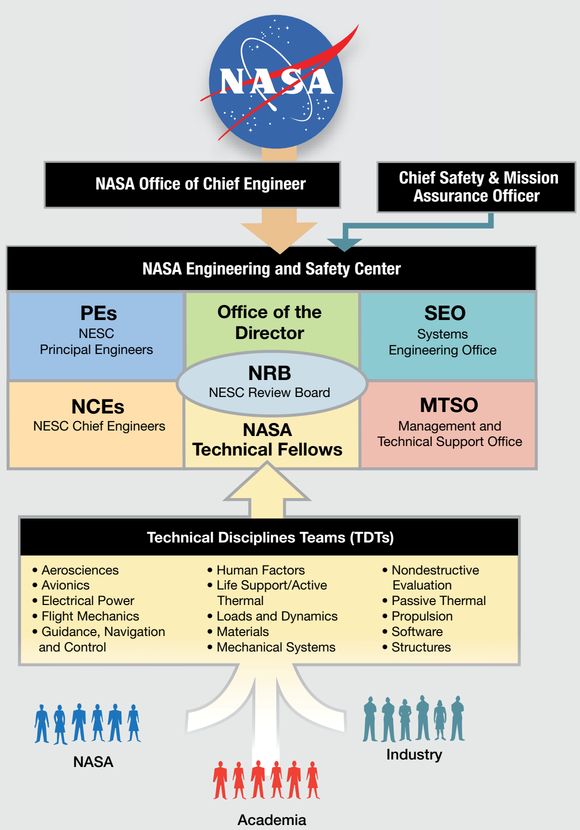
A Unique Agency Resource

The NASA Engineering and Safety Center (NESC) works to ensure safety and mission success by performing independent testing, analysis, and assessments of NASA's high-risk projects. To accomplish this, the NESC has established a model that takes advantage of the diversity of the NASA workforce while reaching out to and engaging the broader technical community outside of NASA. Two unique features of this model are the technical discipline teams (TDTs) and the NESC Review Board (NRB).

TDTs provide a reservoir of experts that supply the members to form teams (called assessment teams) poised to address issues and solve technical problems confronting the Agency. A NASA Technical Fellow leads each team in one of 15 specific technical disciplines. The TDT members are experts in their disciplines and come from across NASA, academia, industry and other Government agencies. The NRB is the decision-making body of the NESC. The Technical Fellows are members of the NRB, along with NESC Chief Engineers from each Center and the rest of the NESC's leadership. This structure brings a diversity that results in robust decisions.

Another important aspect of the NESC is its independence from mission directorates, their programs, and Center leadership. The NESC reports directly to the NASA Chief Engineer and is meant to be a resource for the entire Agency. It also provides an alternate reporting path through which problems can be brought to the surface and addressed.

The NESC Organization



A Diverse Group of Technical Experts

The NESC is organized into 6 offices, which together comprise the NESC Review Board or NRB. The NRB reviews and approves all products and recommendations made by the NESC. The success of the NRB, like that of the NESC model in general, is a result of its broad diversity combined with outstanding technical competence. TDT members are called on to support assessment teams and help address issues being investigated by the NESC.

Principal Engineers Office (PEO)

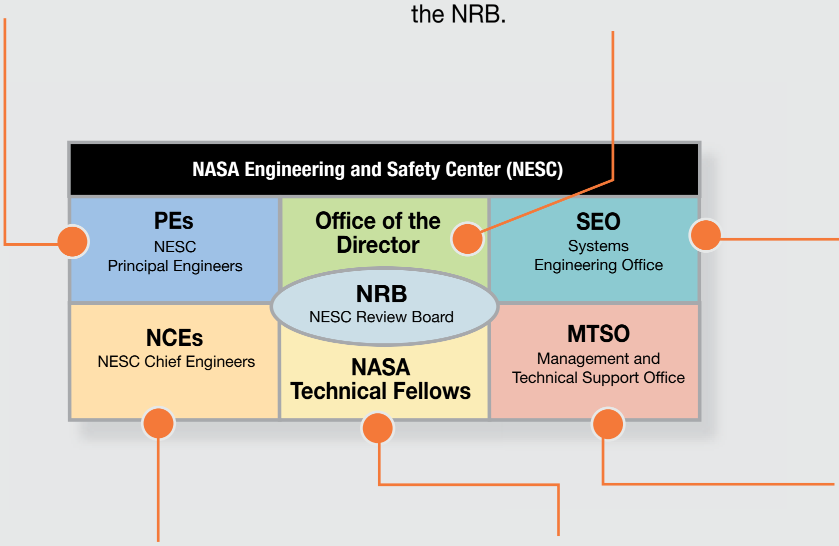
The Principal Engineers Office carries the primary responsibility for the performance of technical assessments. The principal engineers and back-up principal engineers lead assessment teams and provide guidance and assistance for other assessments team leads.

Office of the Director

The top tier of leadership for the NESC is the Office of the Director, which includes the NESC Director, Deputy Director, Deputy Director for Safety, Chief Scientist, and a representative from the astronaut corps detailed to the NESC as the NESC Chief Astronaut. The Office of the Director also chairs the NRB.

Systems Engineering Office (SEO)

The Systems Engineering Office provides system engineering and integration for assessments and other NESC activities. The SEO and the SEO-led Systems Engineering TDT also provide technical expertise in systems engineering processes such as systems analysis, statistics, data mining and trending, and requirements analysis. In addition, the SEO provides the technical integration for the NESC's internal operations, including processing all requests for NESC support.



Management and Technical Support Office (MTSO)

The Management and Technical Support Office is the business office of the NESC and performs the necessary legwork for contracting and maintaining partnerships. The NESC has worked with over 100 companies or individual consultants, with the companies ranging in size from major corporations down to small consulting firms. In addition, several universities and academic institutions have contributed to NESC activities.

NESC Chief Engineers (NCEs)

The NESC Chief Engineers are the primary NESC points of contact at each Center. The NCE's proximity ensures that they can closely track the projects that are active at their Centers. They also help to coordinate the facilities and resources of each Center as required to support NESC assessments and activities.

NASA Technical Fellows

The NASA Technical Fellows are NASA's senior technical experts in 15 engineering disciplines. They are the stewards of their discipline and as such they sponsor discipline-enhancing activities and educate the Agency through workshops and conferences, and oversee online communities.

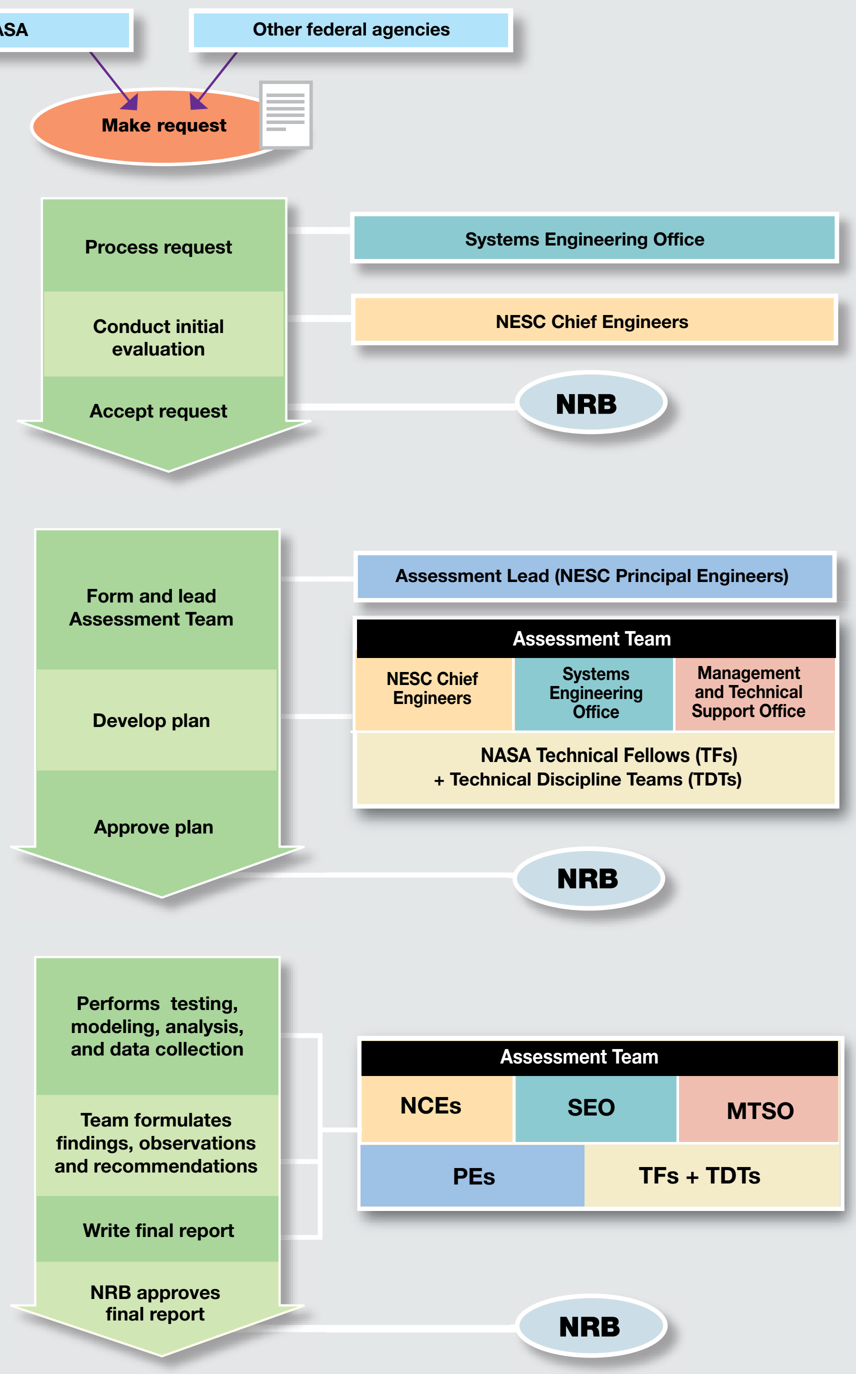
Making Engineering Decisions Based on Data

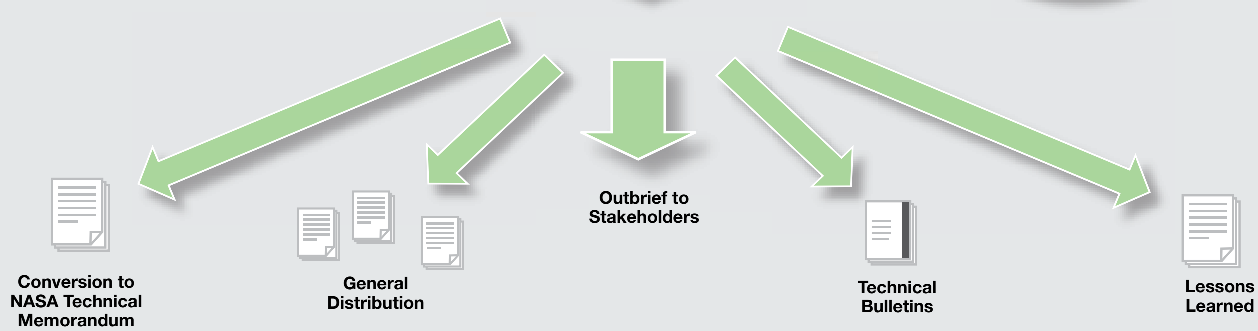
Assessments form the structure and define the process the NESC uses to investigate and solve technical issues. The process outlined below can be tailored to accommodate specific requirements of a given assessment.

1 All requests are screened and an initial evaluation is performed. Recommendations for accepting the task are presented to the NESC Review Board (NRB). The NRB then decides whether to proceed with the assessment.

2 Once the NESC has decided to accept a request, a lead is assigned to form a team to run the assessment, usually from the Principal Engineers Office. Typically, an assessment team will include representatives from the different NESC offices, plus TDT members chosen by the Technical Fellows that possess the skills and expertise needed for the particular assessment. The team develops the assessment plan, which goes back to the NRB for comments and approval.

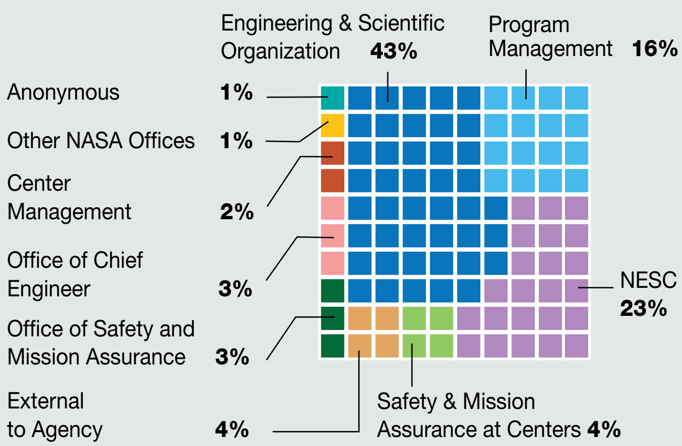
3 After the plan is approved, the team proceeds with the assessment. This may entail testing, data analysis, literature searches, interviews, and modeling. The time-frame for completion can vary from several days to several years. As the assessment draws to a close, the team formulates findings, observations and recommendations drawn from the data produced during the assessment, and publishes them in a final report. The final report is presented to the NRB for approval and then briefed to the stakeholders.



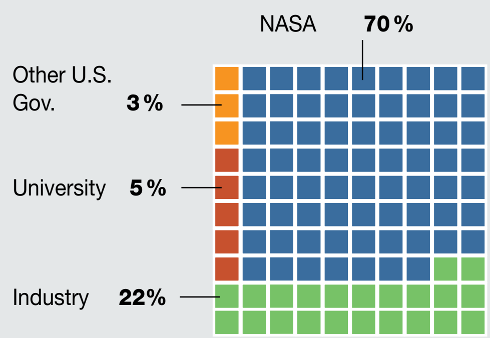


> *The NESC is an incredible technical resource available to help solve complex technical problems and provide independent risk assessments. The NESC will very quickly bring to bear exceptional technical expertise, analysis and testing capability in any required technical discipline to provide an independent assessment. This is crucial given the risks trades we deal with in the Space Shuttle Program.*
>
> — John P. McManamen, Chief Engineer, Space Shuttle Program

Source of Accepted Requests: 389 Total

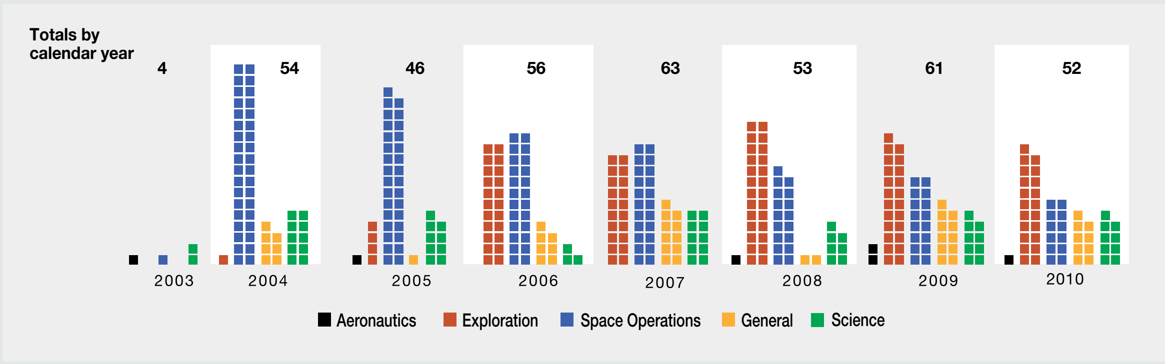


2010 Technical Discipline Team Composition



All statistics as of Nov. 4, 2010

Source of Accepted Requests by Mission Directorate: 389 Total



The Value of Engineering Reports

After performing an assessment, the team develops a final engineering report documenting findings, observations, and recommendations. The engineering report is peer reviewed and approved by NESC Review Board members. Approved reports are not only provided to the assessment's stakeholders but also available to those who require the information for future programs and projects. The report captures all independent test data and analysis performed. Supporting rationale for the recommendations is also recorded. All the data collected serves as objective information for decision makers. While the engineering report informs and benefits the decision makers on the current topic being assessed, additional value is gained from having a resource for other programs and projects to reference when they experience similar issues. The report may also serve as lessons learned or guidance for future programs and projects to follow. Archived engineering reports may be located through the NESC website.

Supporting NASA's Commercial Space Operations Development

In February 2010, the President and the NASA Administrator announced a strategy to increase commercial participation in U.S. human spaceflight. This announcement marked a fundamental change for how NASA would perform their human spaceflight mission in the future and presents a number of challenges to the Agency as it moves into this new era. The NASA Technical Fellows (TFs), together with their Technical Discipline Teams (TDTs), proactively responded to this challenge by participating in technical reviews and interchanges with prospective commercial providers, as well as visits to commercial facilities. In May 2010, the TFs met with potential commercial providers to discuss considerations for launch abort system, landing system, and composite crew module designs. During this exchange, commercial providers had the opportunity to interact with NASA TFs and members of their TDTs to discuss their individual designs. The NASA TFs and their TDTs have also assisted in the identification of standards that might be applied by the commercial sector in the development of crewed spacecraft, as well as the identification of standard modifications and improvements that might better enable the development in a commercial environment.

Administrator Bolden with Members from five companies awarded Space Act Agreements for the development of crew concepts, technology demonstrations and investigations for future commercial support of human spaceflight.

NASA Technical Fellows Perform State-of-the-Discipline Assessments

The NASA Technical Fellows (TFs) are in a unique position to continually assess the state of their disciplines through interactions with their Technical Discipline Teams (TDT) and their participation in a wide variety of NESC assessments and project reviews. They perform a formal state-of-the-discipline (SoD) assessment based on these experiences to highlight successes, challenges, and trends in the readiness of the discipline to address NASA's missions. In these SoD assessments, the TFs present the top discipline technical challenges, which help provide a roadmap for future technology development within specific technical areas. Assessment of the discipline is an ongoing effort that is aided by capturing lessons learned during NESC's assessments. In 2010, five such SoD assessments were completed and communicated to senior NASA management. The NASA TFs for Flight Mechanics, Passive Thermal, Materials, Structures, and Non-Destructive Evaluation all presented their SoD presentations to the NASA Chief Engineer, the Center engineering directors, and the NASA Chief Safety and Mission Assurance Officer. Assessing the SoD is a critical role for the NASA TF and can be an effective tool for maintaining the health and readiness of the technical disciplines and developing technical roadmaps to execute NASA's missions.

NASA Technical Fellow Steven Rickman

Resident Engineer Program Advances to Its Second Year

The NESC Resident Engineer (RE) Program moves into its second year of operation for 2011 with the selection of four new REs. The Program involves the competitive selection of junior engineers that work with the NESC for one year. Selected REs remain resident at their home Centers but are assigned to the NESC. While working with the NESC, the NASA Technical Fellows and Principal Engineers, they gain hands-on experience solving the Agency's toughest challenges. They participate on a number of multi-Center NESC assessment teams and work other projects assigned by a mentor. The goal is to provide the REs with diverse assignments and exposure to multiple sub-disciplines, while developing a broader systems engineering perspective.

The NESC leadership welcomes the new Resident Engineers named for 2011. They are, from left, Kelly Currin/KSC, Jonathan Dickey/SSC, Brian Anderson/JSC and Jared Dervan/MSFC.

Learning About Us Through the NESC Website

The NESC website is a communications tool that makes information available on the NESC's current and past activities. In addition, the NESC has launched a Facebook page, and other tools for public outreach efforts.

The NESC website has a large collection of technical reports and bulletins and information on how to contact the NESC. The information highlights include:

- NESC Technical Reports: All publicly available NESC engineering reports can be downloaded.
- NESC Technical Bulletins: A one-page bulletin released when new engineering knowledge is developed or learned that could be broadly applicable to the larger technical community.
- Technical Update: An annual summary of the NESC's technical activities.
- NESC News: A newsletter designed to help keep the NASA community and public informed of NESC activities. A free subscription is available from the NESC website.
- Contact Information: NASA engineers can contact the NESC either directly or anonymously to request NESC engagement in NASA's technical problems, or contact the NCE at their Center to discuss a potential request for NESC assistance.

On the Web

NESC nesc.nasa.gov
NESC Academy www.nescacademy.org
NASA Engineering Network nen.nasa.gov

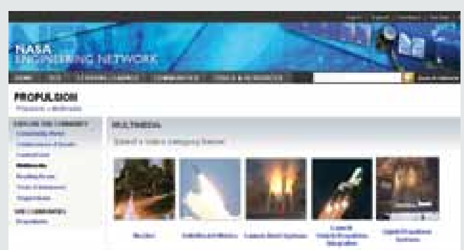
Technical Fellows Engaging Practitioners through Communities of Practice

A community of practice (CoP) is a network of individuals who are dedicated to, and have personal experience in a given engineering discipline. Through the office of the Chief Engineer, the NASA Technical Fellows (TF) have developed online communities as part of their discipline stewardship charter with the goal of sharing knowledge across all the Centers. The CoPs are part of the NASA Engineering Network (https://nen.nasa.gov) and are accessible to all NASA employees.

In 2010 seven new communities and three sub-communities were rolled out, bringing the total of sites to thirteen. In addition, a new community was formed around Autonomous Rendezvous & Docking (AR&D). This unique community is co-led by the NASA TF for Guidance, Navigation and Control and his predecessor.

Membership and use of the CoPs continues to grow. The sites are used to highlight key lessons learned, identify standards and best practices, distribute NESC Technical Bulletins, provide a forum for online discussions, and share videos and papers of interest. A few communities added an Ask an Expert function that allows anyone to pose questions that vetted experts respond to online. Both question and answer are captured and available on the CoPs.

The NASA Technical Fellows encourage all members of each community to contribute their individual knowledge, lessons learned, and other discipline expertise to the CoP sites.



The NESC Academy: Learning From the Past, Looking to the Future

The establishment of the NESC Academy helps ensure that the body of knowledge of senior NASA scientists and engineers remains viable and accessible. The NESC Academy provides the forum through which recognized discipline experts can teach the critical competencies to the NASA workforce. Initially, the classes were a three-day instructor-led course. The course was video taped for online delivery.

The NESC Academy is updating the knowledge capture and delivery method opting for shorter video courses created directly by the Subject Matter Expert of the particular discipline. The focus of the content is to explain and describe NASA technical problems, their solutions, and impart lessons learned.

Going forward, the original Academy courses will be reconfigured and separated into shorter segments with easier web accessibility to the content. A re-design of the NESC Academy website will occur in 2011.

The original instructor-led Academy courses, with the exception of the Innovative Engineering course, are still available online at http://www.nescacademy.org.

TECHNICAL HIGHLIGHTS

The NESC collected data from water drop tests of an Orion boilerplate crew module. The data is being used to improve water drop simulations and was also used by the Orion Project.

Orion Crew Module Water Drop Testing and Modeling

Problem: Water landings of the Orion crew module (CM) will induce non-linear transient dynamics in the CM structure that are difficult to accurately model/predict. Reliable and accurate predictions are essential since water landing is driving critical structural elements of the CM design and overall mass. The Orion Project employed the finite-element tool LS-DYNA® to model the structural design of the Orion CM. In the absence of sufficient experimental data, it was not clear whether the Orion LS-DYNA® model could accurately predict the interaction of the CM with the water during landing, as well as the CM's flexible body structural behavior with any reasonable degree of certainty. While the Orion Project and other NASA programs are critically dependent on the validity of the answers generated by the LS-DYNA® tool, limited test data existed to validate the model predictions.

NESC Contribution: The NESC performed a series of controlled drop tests of a full-sized Orion CM boilerplate to characterize vehicle responses to water impact and compare the results with model predictions. A team was formed with subject matter experts from GSFC, GRC, JPL, KSC, LaRC, WFF, JSC and industry contractors/consultants to conduct the testing in a littoral facility at the United States Army Aberdeen Test Center. The CM simulator was instrumented to measure rigid body accelerations at the vehicle's center of gravity and preliminary heat shield pressures and strains. Data sets were obtained for two vertical drop entry angles at nominal descent velocities. Test predictions were generated from an LS-DYNA® model of the boilerplate CM using the Orion Project's fluid mesh and modeling parameters. Measured water contact conditions, including CM attitude and velocity, were used to initialize the simulations to enable a direct comparison of the measured data and simulation results.

Results: The simulation predictions and drop test data showed inadequate correlation. Comparison of predicted and measured acceleration data indicated improvements were necessary in the modeling approach. Subsequently, a refined water mesh was developed and an alternate method for characterizing the fluid-structure contact was implemented. These changes led to a strong correlation between the accelerations generated by the LS-DYNA® model and the test data. A second set of water drop tests are planned for early 2011 to measure heatshield pressures and strains. The independent drop tests and subsequent evaluation were being used by the Orion Project, providing early risk mitigation for the next crewed vehicle.

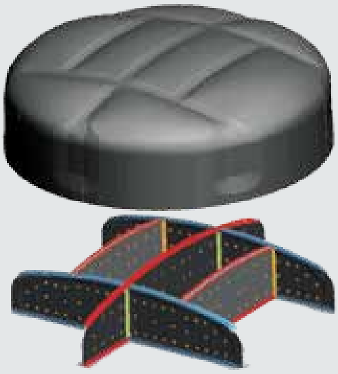
Test drop of an Orion crew module boilerplate to measure the acceleration profile at the vehicle center of gravity. A total of 18 drops were performed at the US Army's Aberdeen Test Center, MD. The CM was previously flown on the Max Launch Abort System Project.

The composite crew module installed in LaRC's Combined Loads Test facility undergoing static internal pressure testing to failure.

Composite Crew Module Pressure Vessel Completes Element Testing

Problem: In January 2007, the NASA Administrator and Associate Administrator for the Exploration Systems Mission Directorate chartered the NESC to design, build, and test a full-scale crew module (CM) primary structure, using carbon fiber reinforced epoxy based composite materials. The overall goal of the Composite Crew Module (CCM) Project was to develop a team from the NASA family with hands-on experience in composite design, manufacturing, and testing in anticipation of future space exploration systems being made of composite materials. The CCM Project was planned to run concurrently with the Orion Project's baseline metallic design within the Constellation Program so that features could be compared and discussed without inducing risk to the overall Program.

NESC Contribution: During the design phase, the team constrained the design to match interfaces with the then-current Orion CM, including the internal packaging system that utilized a backbone for securing internal components. The team evaluated several design solutions and focused on one configuration that uses a composite sandwich structure with transitions to composite laminate at heavily loaded attachments. A unique feature of this composite design is the use of lobes between the webs of the backbone structure. This complex shape, enabled by composite technologies, places the floor into a membrane-type loading condition, which provides mass savings for the composite design and the adjacent heat shield system. The highly loaded and geometrically complex backbone-dome attachment was enabled by three-dimensional woven preform technology. By connecting the aft dome to the backbone and placing lobes into the floor, designers realized a mass savings of approximately 150 lbs to the overall primary structure design.



CCM pressure vessel lower shell and backbone

The test article is constructed in two major components: upper and lower pressure shells. The two halves are joined in a process that does not use an autoclave, which enables subsystem packaging of large or complex subsystems, such as plumbing and cabling, prior to assembly.

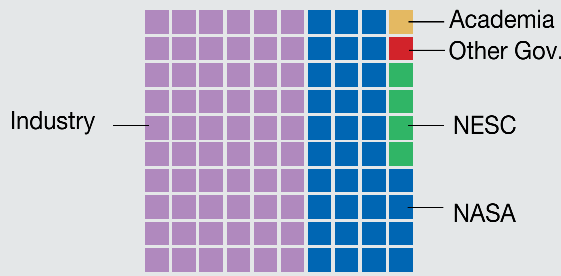
Results: The full-scale test article was delivered to LaRC and testing of critical features began. The test article was subjected to combined loads of internal pressure and static pull on critical

Wade Jackson and Dr. Sotiris Kellas from LaRC delivering impact damage to the CCM using a custom-made impact tool.

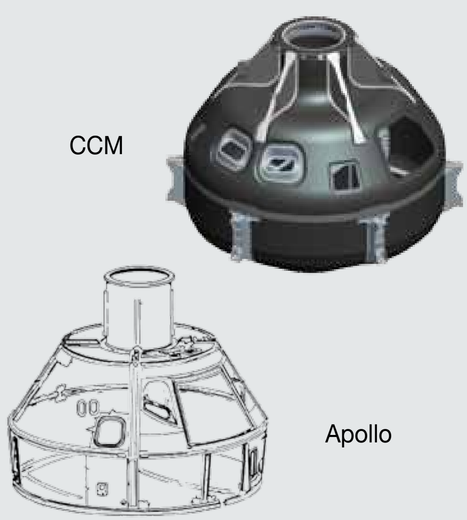
About the CCM Team

Like most NESC teams, the CCM Project team is a collaborative partnership between NASA and industry, which includes design, manufacturing, tooling, inspection, and testing expertise. Partners include civil servants from nine NASA Centers, the Air Force Research Laboratory, and contractors from Alcore, Alliant Techsystems, Bally Ribbon Mills, Collier Corporation, Genesis Engineering, Janicki Industries, Lockheed Martin, Northrop Grumman, and Tayco. The team is organized such that all participants conduct work based on their individual expertise, regardless of their company or Center affiliation. The result is an integrated team with civil servant and contractor participants distributed within and across each of the Project disciplines. The CCM team operates across four time zones, in a virtual environment, connecting participants across the country.

CCM team makeup by percentage



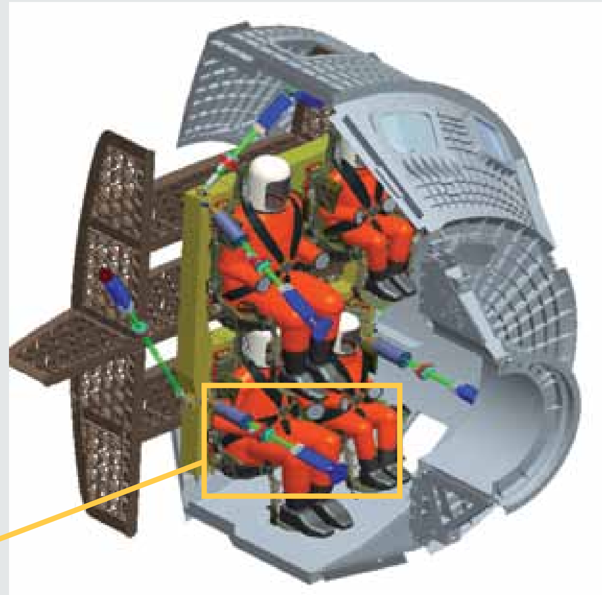
interfaces to design limit loads and ultimate loads to verify how accurately the analysis models predicted the response of the structure under load. The test article was instrumented with approximately 300 traditional strain gauges, 3,500 state-of-the-art fiber optic strain measurements, and six different two-dimensional full-field strain measurements. The measured strains correlated to the predicted strains well within the 20-percent goal. Upon completion of the static testing, the test article was initially subjected to impact damage of 6 foot-pounds (ft-lbs) at locations representing different states of stress. The impact damage was inflicted by using a custom-made, spring-loaded plunger with a 0.5-in. hemispherical impact head. The 6 ft-lbs level was selected as a "credible threat" because it represented the level of damage that could occur as a result of a tool drop during spacecraft integration. The test article was then subjected to similar static tests at design ultimate levels and cyclic loading to see if the damage showed signs of growth. The test article was subjected to even greater damage, up to 26 ft-lbs in critical regions, and the testing was repeated to design ultimate levels and with cyclic loading. In all cases the test article showed no measurable defect growth at the damage locations. The final test for the CM was a static internal pressure test to failure. The final internal pressure achieved was 53.2 lb/in^2. Failure occurred at the shoulder in the upper shell where the conical section meets the ceiling and appeared to be a disbond between the inner composite skin and the honeycomb core. This was caused by excessive through-thickness tension as the ceiling radius deflected under the internal pressure.



Comparison of Apollo and CCM pressure vessels

Overall, 2010 focused on testing, specifically damage-tolerance testing, cyclic-load testing, and a hydrostatic test to failure. Finite element model analysis using both coarse- and fine-grid models provided exceptionally good correlation with measured results. Non-destructive techniques, including single side pulse echo ultrasound and flash infrared thermography, were effective methods for characterizing damage both in sandwich systems and solid laminates.

Fullscale seat strut energy attenuation device being tested at NASA Langley Research Center's Landing and Impact Research (LandIR) facility.



(Left) Isolator in–line with Wire Bender Strut Assembly and (above) the design concept intended to minimize the loads to the crew through all phases of flight.

Development of Orion Crew Seat Energy Attenuation Mechanism Concepts

Problem: The Orion Project requested that 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). Emphasis was placed on the Project-directed goals of improving robustness and maximizing crew protection from acceleration forces. Due to the team's in-depth knowledge of the problem and work with isolation systems, the NESC was later asked to evaluate design options in the crew seat area that mitigate the Ares I thrust oscillation (TO) environment and evaluate any effect on crew response to landing loads.

NESC Contribution: The assessment team consisted of designers and analysts from multiple NASA Centers including GSFC, GRC, JSC, JPL, and LaRC; contractors; and academia. Based on the Orion Project's review of the alternate concepts, the NESC team focused detailed design and analysis efforts on investigating the effectiveness of incorporating an isolation system between the seat pallet and the CM pressure vessel structure. The NESC team developed simplified dynamic response models and utilized the Orion baseline models to examine a range of pallet isolation properties for crew landing attenuation. Analytical tool development and pallet isolation analysis were used to examine mitigation concepts for TO from the Ares I first-stage solid rocket booster on the crew using pallet isolation. Coupled loads models for launch and landing models using Nastran, LS-DYNA®, and Adams multi-body dynamics software were used to examine the optimal TO isolation frequency that would minimize crew loads during all phases of the Orion flight. In addition, hardware design concepts for implementation of this feature have been generated, hardware has been built, and testing is in process. The NESC team built a set of pallet isolators incorporating the frequency and stiffness requirements from the Nastran launch models. Friction dampers were added to the design to mitigate Launch Abort (LA) dynamic loads. Proof of acceptability came from LA runs in LS-DYNA® that compared impact results (with and without the dampers) using the Brinkley whole-body injury model. The NESC team continues to evaluate the effect of passive pallet isolation on the crew for landing impact. To date, model correlation is improving through lessons gained from testing.

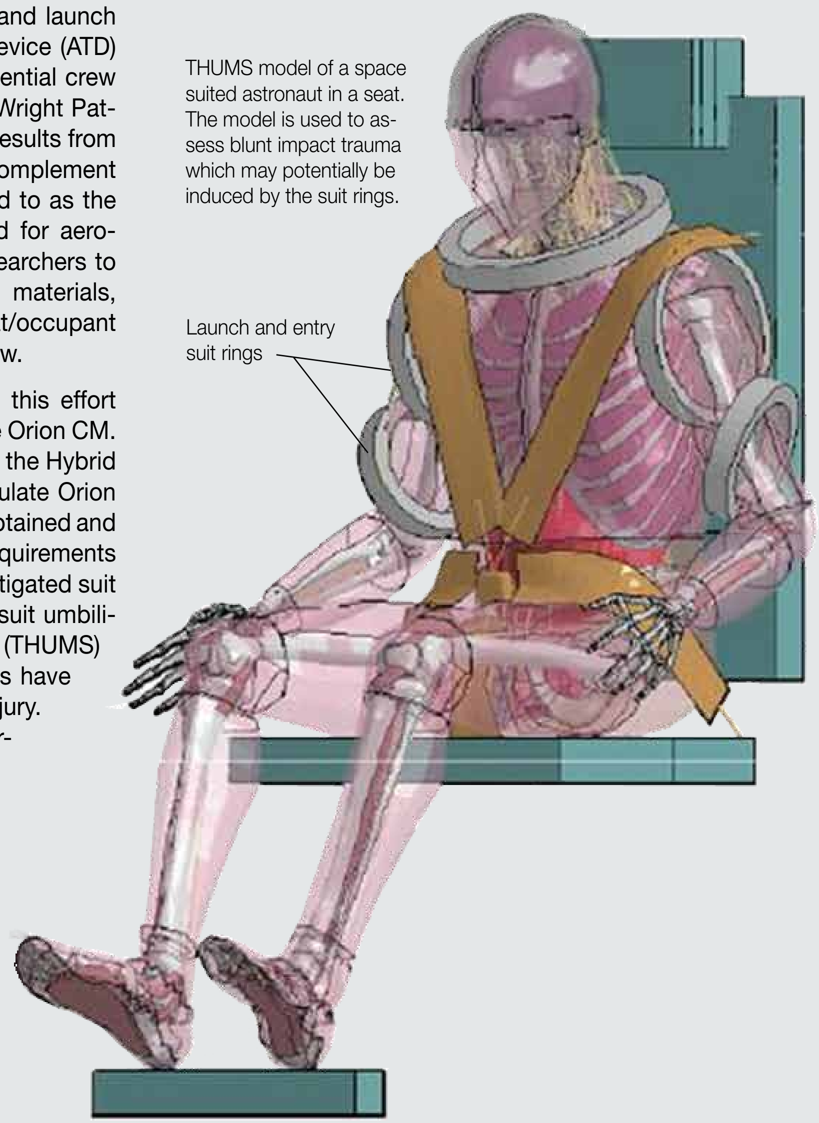
Results: The TO study confirmed the optimal crew isolation frequency and revealed a potential problem with a rocking mode of the crew seat should isolation be implemented at that location. The NESC team also found the pallet isolation approach to be advantageous from a load mitigation perspective. Isolating in series with the pallet struts has a lower effect on crew landing loads than seat isolation and a higher probability of successful implementation. The NESC team built prototype hardware and began testing to determine the effectiveness of the isolation frequency on crew performance during the TO event and the isolators' contribution to landing impact loads on the crew. Isolator-level performance, strut impact, and system impact tests are complete. Results of these tests drove changes to the math models for correlation. The information gained from these tests will be helpful in developing models for exploration landing systems. In addition, the crew pallet isolators provide mitigation against dynamic loads on the crew from the launch event. The NESC team is also evaluating active systems to improve the strut performance over the baseline for all landing cases. This technology is being developed in collaboration with academia.

Evaluation of Orion Occupant Protection through LS-DYNA® Modeling

Problem: Reliable injury predictive tools and injury criteria are required to ensure that human-rated spacecraft such as the Orion crew module (CM) or a commercially provided low-Earth orbit vehicle be designed with the appropriate level of occupant protection. Conventional tools used in the aerospace community have typically led to safe designs. Once the Space Shuttle is retired, NASA is expected to transition to a new spacecraft whose primary landing mode will likely use parachutes and be water based (with contingency land landings). This new spacecraft will introduce many challenges not seen since the Apollo Program. Approaches to ensure safety, such as those used in the automotive industry, may provide a foundation for human-rated space flight; however, their application to future or commercial spacecraft requires modification and study.

NESC Contribution: The NESC is developing injury criteria and methods for predicting injury for the Orion CM and future commercial space programs. These criteria and methods maximize crew member safety during critical phases of flight such as nominal and off-nominal landings and launch abort. The Hybrid III anthropomorphic testing device (ATD) has been thoroughly evaluated for assessing potential crew injuries through extensive impact sled testing at Wright Patterson Air Force Base and numerical modeling. Results from these finite element models are being used to complement the whole-body injury models (commonly referred to as the Brinkley criteria) which have been typically used for aerospace applications. The ATD models enable researchers to assess the occupant restraint systems, cushion materials, side constraints, flailing of limbs, and detailed seat/occupant interactions to minimize landing injuries to the crew.

Results: The injury criteria developed through this effort have been applied to suited crew members for the Orion CM. Numerical models of a suited crew member using the Hybrid III and a pressurized suit have been used to simulate Orion CM landing conditions. Injury criteria have been obtained and compared to the Human Systems Integration Requirements allowable limits. Additionally, the NESC has investigated suit trauma by evaluating two design options for the suit umbilical connector. The Total HUman Model for Safety (THUMS) has been used to assess injury risk and remedies have been developed to protect crew members from injury. The NESC and JSC Space Life Sciences Directorate (SLSD) organized a meeting to develop a proposed definition of acceptable landing injury risk for Orion crew members. Attendees included NASA, military, and civilian experts in biomechanical modeling, operations, and medicine; and occupant protection designers. The team reviewed a proposed Operationally Relevant Injury Scale (ORIS), which analyzes potential crew injuries in relation to three parameters: the Abbreviated Injury Scale (AIS) rating, potential impact on crew self-egress capability, and estimated impact on the crew member's ability to return to flight status. The result was an injury classification, on a four-point scale, which was derived through relative weighting of the above factors. The JSC SLSD and the NESC organized a meeting focused on occupant protection during dynamic phases of flight in human-tended spacecraft. Participants included members from NASA, the aerospace contractor community, U.S. military, academia, National Association for Stock Car Auto Racing, Indy Racing League, National Highway Transportation Safety Administration, and the Federal Aviation Administration. The purpose of the meeting was to discuss potential follow-on work including further testing and analysis, development of additional analysis tools and techniques, occupant protection requirements, and potential test requirements to assess the level of occupant protection afforded by future vehicle designs.



THUMS model of a space suited astronaut in a seat. The model is used to assess blunt impact trauma which may potentially be induced by the suit rings.

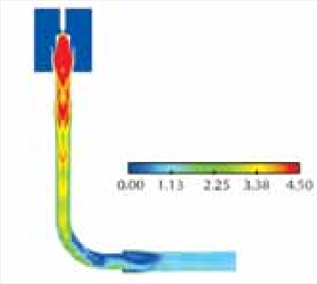
Examination of the Altitude Simulation Capabilities of SSC's A-3 Test Stand

Problem: Risk reduction sub-scale projects to validate the A-3 Test Stand design uncovered a critical issue: The chemical steam generators (CSGs) used to create vacuum conditions produce concentrations of free oxygen that react inside the diffuser with un-burned hydrogen from the engine, creating an "un-start" condition which reduces the flow of steam and negates the effectiveness of the diffuser. This afterburning can also produce temperatures and pressures that could cause structural damage to the diffuser. The A-3 Test Stand presents critical technological challenges that require in-depth understanding of the operation of the CSGs. The A-3 Test Stand is scheduled to test the developmental J-2X Engine at simulated altitude conditions by blowing steam at high speeds through the diffuser to create vacuum conditions in the engine test cell.

NESC Contribution: The NESC supplied independent subject matter experts to a senior review team chartered to assess the identified problems. The NESC experts interacted with the SSC design team in a series of technical interchange meetings.

Results: The NESC team offered suggestions to increase CSG system robustness and reliability. These included clarification of the engine nozzle wall pressure differential, minimization of secondary combustion in the diffuser system, and a common steam supply for two ejectors.

CRAFT Tech



(Above) Subscale diffuser for design validation of NASA Stennis Space Center's A-3 Test Stand.

(Left) Mach number distribution showing predominantly subsonic flow in the diffuser (dark blue color along the elbow).

Ultimately the NESC team concurred with the SSC design team's solution for minimizing afterburning in the diffuser system.

Structural Dynamics Analysis Review of SSC's A-3 Test Stand

A section of the test cell is lifted for installation on the A-3 test stand's structural steel frame. Work on the A-3 Test Stand began in 2007. It is scheduled for activation in 2012.

Problem: The A-3 Test Stand under construction at SSC consists of an open-frame steel structure that supports the engine and large test-stand components. The A-3 Test Stand is designed to provide high-altitude condition testing for large-thrust, liquid-fueled engines. Significant acoustic environments will be generated during operation of the test stand and supporting facilities. This may result in significant vibratory response from the stand and could have negative implications on electronics, metal fatigue, engine interface environment, facility mechanical components, and the local environment. Vibroacoustic environments were not explicitly addressed in the design phase and SSC lacks the resources and expertise to perform such a detailed analysis.

NESC Contribution: At the request of the A-3 Test Stand Chief Engineer, the NESC formed a team of technical experts from the NESC, the NESC Technical Discipline Teams (TDTs), SSC, and MSFC to explicitly address the predicted vibroacoustic environment and its potential impact to collateral systems. The team gathered data from sub-scale testing previously performed at SSC, drawings, and the static analysis model. A variety of complex dynamic analysis models was generated by the team, which will characterize test operation vibroacoustic environments at locations of concern.

Results: The team completed the assessment and pre-briefed the requester of the results. Deliverables will include the stakeholders' briefing, report, data, and models.

Ares I Control System Sensitivity to Orion SM Tank Slosh Dynamics

Problem: During the early development phase of the Ares I launch vehicle, propellant slosh dynamics in the Orion service module (SM) tanks were subjecting the launch vehicle flight control system to potentially destabilizing forces. The baseline Orion SM tanks are unbaffled, smooth-walled composite overwrapped pressure vessel designs, which provide very low resistance to propellant slosh during ascent. The Ares I flight control system could not meet stability and control margin requirements with the Orion SM tank slosh dynamics models. The Constellation Program requested NESC provide an independent review of the Ares I launch vehicle control sensitivity to the Orion SM propellant tank slosh dynamics.

Mechanical technician Arnold Kuchenmeister adjusts one of the SM's engine propellant tanks in a mock-up of an Orion SM at GRC.

NESC Contribution: The NESC team divided the independent review into three primary subtasks. The first subtask was a thorough review of the Orion SM tank slosh dynamics models and the implementation methods of these models into the Ares I simulations. The second subtask was to review the plan for an Ares I tank slosh dynamics test. This test, designed to provide data for the Ares I upper stage oxygen and hydrogen tanks, would also provide validation data for the Orion SM tank models. The test hardware and instrumentation were also reviewed. An evaluation was performed on the state-of-the-art in computational fluid dynamics predictive capabilities for smooth-walled tanks (with and without baffles). In addition, a conceptual lightweight baffle design was developed, which could provide increased damping to mitigate the Ares I control sensitivities. The third subtask was focused on the Ares I Guidance, Navigation, and Control (GN&C) design and analysis. A team of NESC experts met with the Ares I teams to examine the launch vehicle architecture, the Ares I stability and flight performance requirements, and legacy GN&C references from the Saturn designs. The NESC team conducted a detailed review of the Ares I GN&C analysis methodologies and tools, analytic assumptions, modeling techniques, and the analysis results.

Results: The NESC concluded that despite both the Ares I and Orion teams utilizing best practices, assumptions, and methodologies, a flight control system design using existing architecture — that would accommodate the low damping values in the unbaffled Orion SM tanks — could not be identified. The NESC recommended the Orion Project pursue a tank redesign that would increase the minimum damping value, and the redesigned Ares I GN&C systems use this updated value to ensure robust stability and control margins exist throughout all ascent phases.

Mercury, Gemini, Apollo, and Space Shuttle programs made different determinations on the appropriate time to fly a crew for the first time.

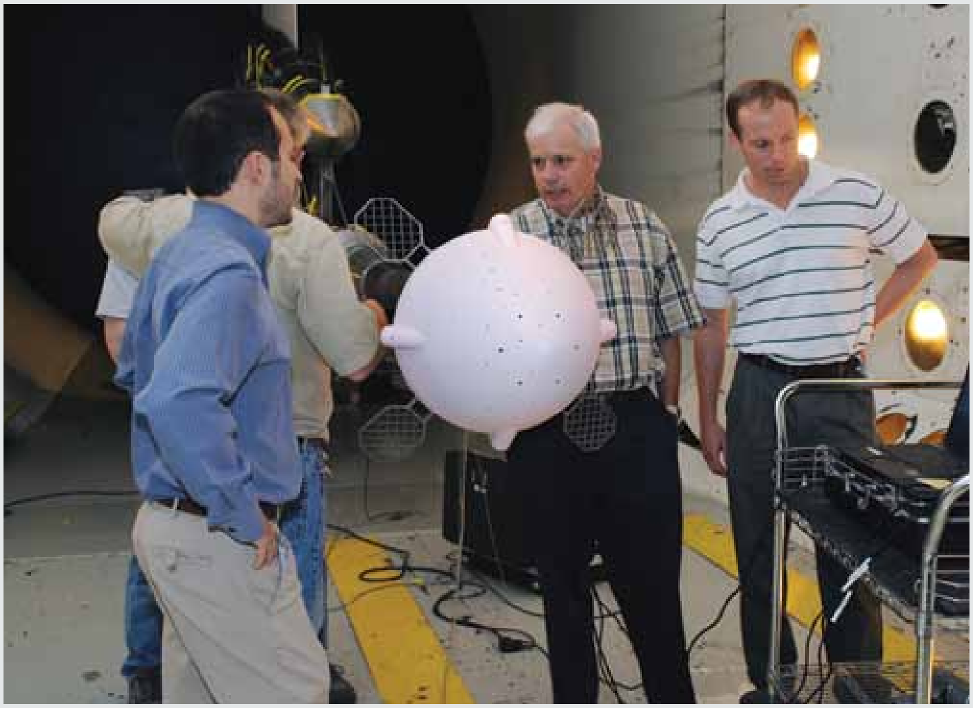
Determining Readiness for Crewed Flight on New Spacecraft Systems

Problem: The NESC was requested to develop a framework to help Agency and program decision makers determine when to allow crew members to fly on a new human spaceflight system for the first time.

NESC Contribution: The framework will be applicable to both NASA and commercially developed systems. As a benchmark, the NESC team met with representatives from the United States Navy and the Air Force Flight Test Center to discuss their approaches to first crewed operations. An extensive literature search of past NASA programs was also conducted.

Results: The decision on first flight with a crew is ultimately a judgment call by the program and Agency leadership. However, there is some general guidance that can be used in making these judgments. Based on previous experience, historical perspectives, and best practices, the NESC team matured and evolved the framework into a narrative describing the key contributors to successfully understanding the residual risk of first flight with a crew, along with methods to increase confidence in the decision-making process. The team plans to perform a pathfinder exercise by using this framework to evaluate the next human spaceflight system test program.

Launch Abort System Concept Study for Crew Safety



Dr. David Schuster (center), NASA Technical Fellow for Aerosciences, Dr. Jeremy T. Pinier (left) and David Witte (right), both from NASA Langley Research Center, discuss grid fins during set up of the MLAS model prior to testing.

Problem: NASA must continue to gain the necessary insight to ensure crew safety. Toward this goal, the Objective System Conceptual Study for the Max Launch Abort System is the continuing effort associated with producing realistic flight vehicle options for an alternate design launch abort system. This effort is leveraging the accomplishments of the NESC-sponsored Max Launch Abort System flight test that successfully flew in July 2009.

NESC Contribution: The NESC is currently developing design alternatives for a capsule-type launch abort system, capable of flying on multiple launch vehicles. This effort is utilizing the NESC's Agency-wide teaming model to matrix expertise from across NASA in disciplines critical to flight crew safety. This approach allows engineers to continue off-line development work of their respective systems, while gaining the knowledge and experience they will need to be "smart buyers" of commercial systems. Only through hands-on design, development, and test work will NASA be able to maintain and expand the expertise required to ensure crew safety in the future. Numerous design options have been explored, resulting in two leading candidates currently undergoing analysis, modeling, and testing.

Results: The NESC will provide recommendations to future programs or entities regarding design options and additional studies for specific analysis, testing, and/or modeling to gain additional knowledge and experience associated with launch abort systems.

PA-1 Attitude Control Motor Controller Board Failure Investigation Support

Artists concept of a high altitude abort sequence.

Problem: The Pad Abort-1 (PA-1) test vehicle attitude control motor controller DC/DC buck converter experienced repeated failures during board- and box-level testing and poses a significant risk to meeting the PA-1 test schedule.

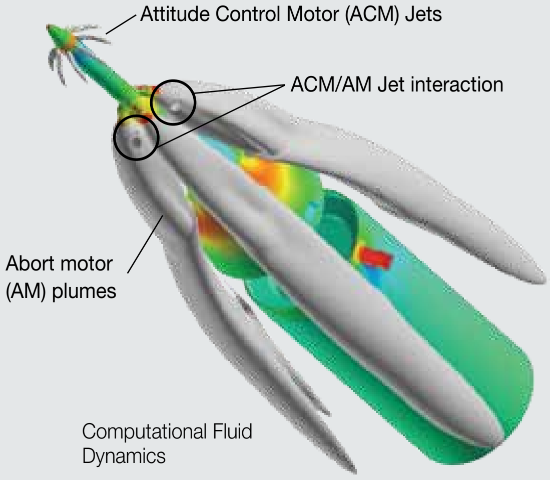
NESC Contribution: The NESC was requested to participate in the Failure Review Board (FRB) and follow-up meetings to assist in determining proximal cause of the failures and provide recommendations for correcting the problem.

Results: After evaluation, the FRB determined the layout design of the controller printed circuit board was enhancing inductive transient voltage spikes on the high-frequency buck converter chip and causing the frequent failures. Recommendations to improve the design were provided and the PA-1 full firing test was subsequently successfully completed.

Review of Orion Launch Abort Vehicle Jet Interaction Aerodynamics

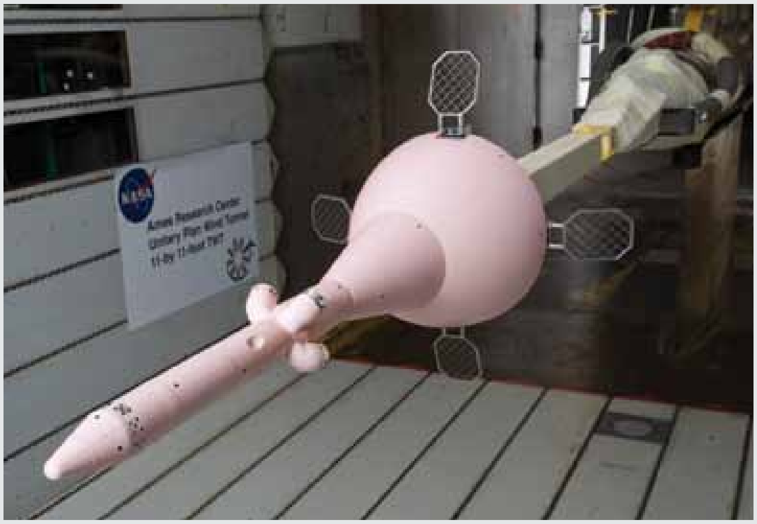
Problem: The Orion Project Launch Abort Vehicle (LAV) is designed to carry its astronaut crew safely away from the Ares I launch vehicle in the event of a catastrophic failure. The LAV is controlled using a series of jets that maintain its attitude and trajectory as it travels away from the failing launch vehicle. At certain flight conditions the effectiveness of this control system has been shown to be degraded due to complex interactions between its thruster and control motor rocket plumes. An independent investigation of these rocket plume interactions was requested by the Orion Project.

NESC Contribution: The LAV is a complex control system that is difficult and expensive to test in a wind tunnel, so the Project has relied heavily on computational fluid dynamics (CFD) to perform design studies and predict performance. The NESC is performing independent CFD analyses, to further validate the LAV design and identify areas of highest risk in the application of the analyses.

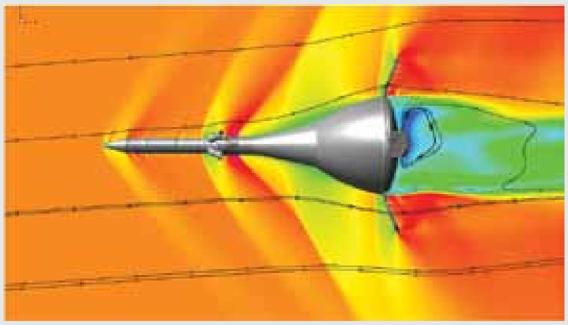


CFD analysis was used to study interactions between the LAV's rocket plumes and attitude control motor plumes.

Results: The NESC will provide data generated using methods independent of those used by the Project. Comparison of these two data sources will help better quantify uncertainty in the analyses and provide higher confidence in the Orion/LAV vehicle design.



Aerodynamic performance testing of the LAV configured with grid fins in the ARC Unitary Plan Wind Tunnel.



Computational Fluid Dynamics analysis of LAV configuration.

Orion Launch Abort Vehicle Stability Augmentation Study

Problem: The Launch Abort Vehicle (LAV) employed by the Orion Project employs a complex active control system to maintain its attitude and trajectory during flight. The present control system may not be adequate to maintain vehicle stability in certain flight regimes, particularly transonic flight. The Constellation Program (CxP) requested the NESC to investigate alternative methods for stabilizing the LAV as risk reduction for times when the control system was inadequate at these conditions.

NESC Contribution: Under the Max Launch Abort System Project, the NESC proposed the use of grid, or lattice fins as a mechanism for enhancing vehicle stability. These control surfaces have been used by other launch vehicles, most notably the Russian Soyuz spacecraft. The NESC is leveraging this experience to develop and test a set of grid fins that could be employed on the Orion LAV to increase stability.

Results: The NESC is investigating the aerodynamic performance and structural and mechanism design for better ways to perform weight estimates and accomplish integrated simulations of a LAV concept with grid fins installed. This study will also propose additional concepts and strategies for stability augmentation. This information will enable the CxP to determine the best approach to stability augmentation should it be required.

Assessing CxP Risk Mitigation Through the Use of CASE Tools

Problem: The Constellation Program (CxP) started capturing system requirements at Levels II and III using computer-aided software engineering (CASE) tools in an effort to analyze the system behavior across the Ares I and Orion vehicle interfaces. Computer-aided design (CAD) tools perform a similar function for mechanical disciplines. The CxP requested the NESC to perform an independent assessment to capture the lessons learned and best use of these CASE tools.

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 I and Orion system development teams. The CxP CASE tool process successes 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.

Results: The NESC team has completed Phase I and initiated Phase II. Within Phase I the team assessed the process and difficulties in using these CASE tools to capture and analyze the behavior of the Orion and Ares I vehicle interfaces. In one effort, the text requirements for the Ares I/Orion abort requirements were modeled to analyze the communication states between these two systems. Building the executable models allowed automated and manual analysis and determined nominal and off-nominal behavior, incorrect requirements, and missing requirements.

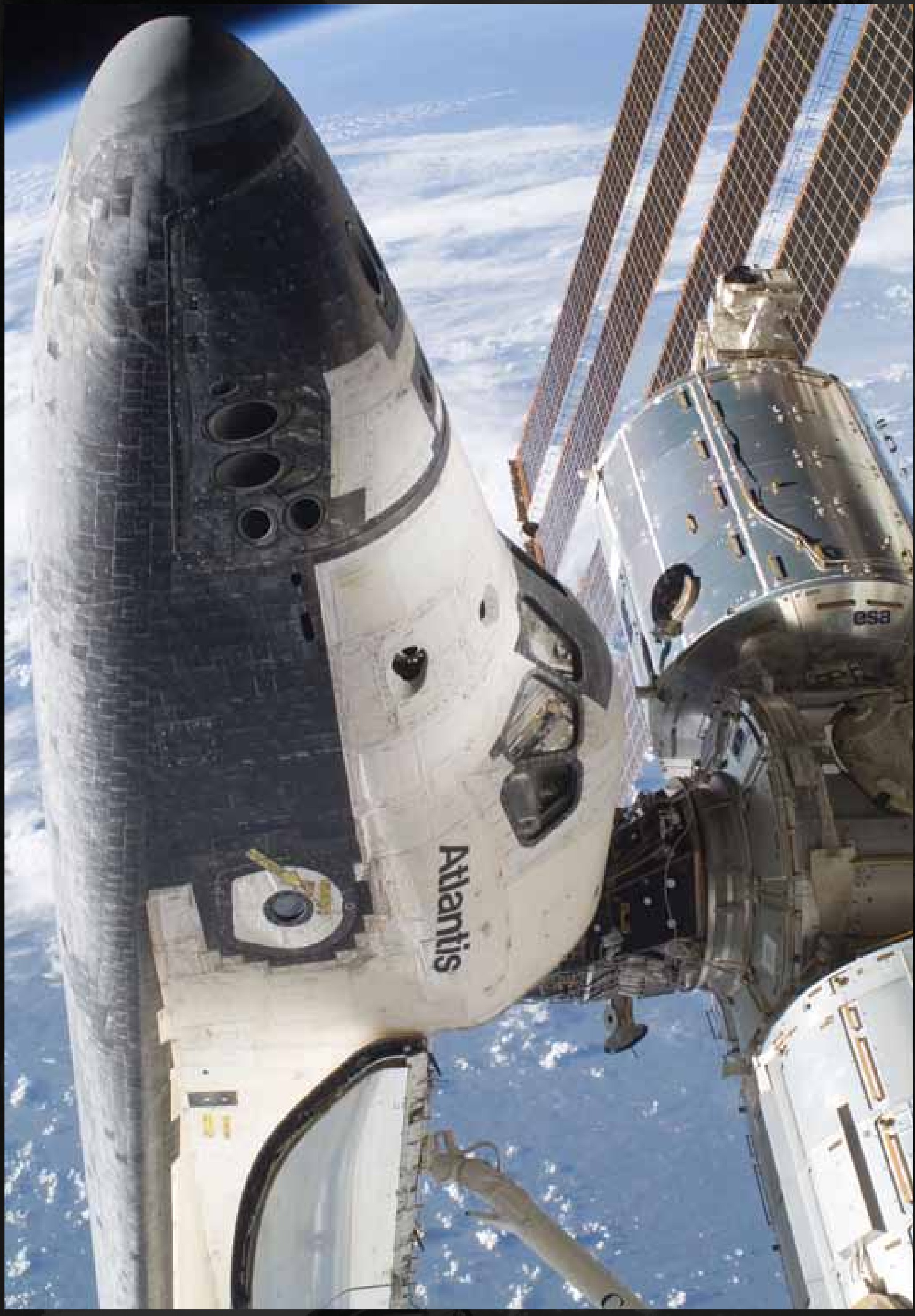
Ares I-X Launch Drift Support

Problem: NESC was requested by the Kennedy Space Center Safety & Mission Assurance (S&MA) organization to provide an independent technical assessment of the Ares I-X launch drift during lift-off from the launch pad. The S&MA concern was that flame impingement on pad structures from greater than expected vehicle drift could weaken the structure and present an unknown hazard to the ground operations crews.

NESC Contribution: NESC experts from the Flight Mechanics, Loads & Dynamics, Structures, and Guidance, Navigation, & Control Technical Discipline Teams assessed both the vehicle drift analysis and the flame impingement analysis on the pad Fixed Service Structure (FSS) and Vehicle Stabilization System (VSS).

Results: The environmental modeling, structural analyses, and resulting allowable launch drift envelope definition were adequate for assuring that the VSS and Ares I-X access structures would not incur gross structural failures during the launch of Ares I-X. However, there were numerous recommendations for future Ares analysis and modeling, including: additional peer reviews, better coordination of ground and flight loads analysis and modeling, and improvements to ground system structural models.

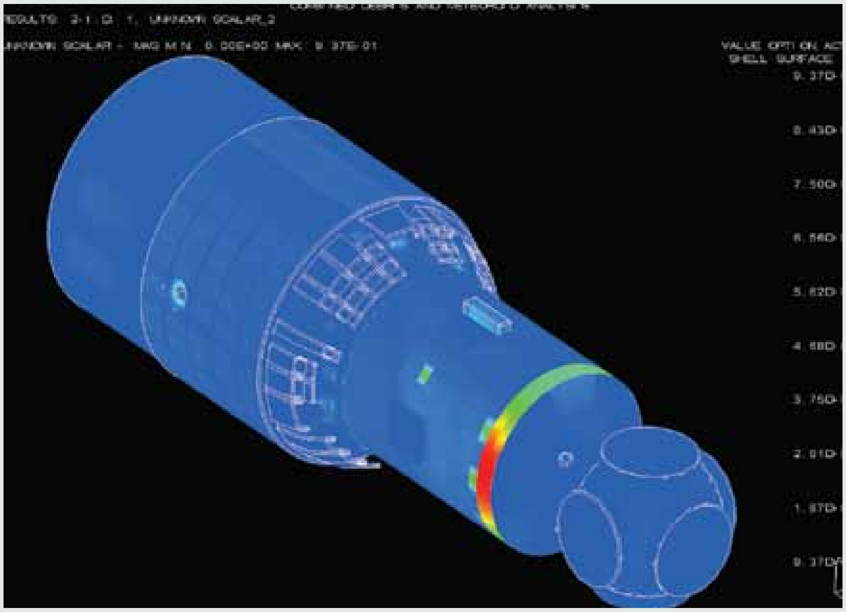
For complex software systems with a large number of requirements and capabilities, CASE tools may be used to help simplify the definition and design of interfaces between major components, such as between the Orion spacecraft and Ares launch vehicle.



The NESC continued to perform assessments on the Space Shuttle to support safe fly-out of the remaining missions.

MMOD Shielding for the ISS Russian Modules Review

Problem: Two Russian modules on the International Space Station (ISS), the Mini-Research Module-2 (MRM-2) and the Service Module (SM), do not meet requirements for protection from micrometeoroids and orbital debris (MMOD). The ISS Program requested the NESC to propose concepts for on-orbit augmentation of Russian module MMOD shielding and to evaluate previously proposed shield designs.



Color-coded contour of the highest MMOD-risk regions of the surface of the ISS Service Module.

NESC Contribution: During this activity, the primary Russian contractor for the ISS, Korolev Rocket and Space Corporation Energia (RSC-E), developed shield augmentation for both modules. The NESC team evaluated the RSC-E MMOD shield designs. The team evaluated the probability of no penetration (PNP) for the two modules using the RSC-E-augmented shields and compared the results to the requirements. In addition, the team suggested possible modifications to further enhance the MMOD protection. The team also evaluated earlier proposals for increasing the protection on the SM. These included moving the SM solar array to a permanently vertical position to act as an MMOD shield and installing a set of retractable panels that would project out of the SM's side to shield the highest-risk areas.

Results: The team determined that the RSC-E designs, while decreasing the risk for both modules, did not decrease the risk sufficiently to meet their respective ISS requirements. The team has quantified the effect of different options on module PNPs and continues to work on providing recommendations to the ISS Program.

Expendable Launch Vehicle Pyrovalve Reliability and Safety Policy Review

Problem: Personnel safety concerns increase when expendable launch vehicle (ELV) payloads contain hazardous commodities such as hydrazine or nitrogen tetroxide (N204). Pyrotechnic-operated valves (pyrovalves) are often used in propulsion systems to isolate and control these propellants. Payload safety reviewers and spacecraft programs have not always agreed on the number of mechanical inhibits that pyrovalves represent in meeting safety requirements and 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. NASA Payload Safety requested an assessment to clarify Agency payload safety policies.

Assessment Lead Regor Saulsberry (left) and Deputy Steve Woods from WSTF, discuss pyrovalve configurations.

NESC Contribution: An assessment is in progress to ascertain the number of inhibits the pyrovalves represent and to determine if leakage is a credible concern. Also, to ensure safe application to ELV payloads, pyrovalve requirements were reviewed in areas of design, fabrication, quality assurance, and testing. The products from the assessment will assist the ELV payload safety community in developing payload safety policies regarding pyrovalves.

Results: A team of subject matter experts is evaluating the minimum requirements for reliable pyrovalve operation, and draft requirements have been written. Other expert sub-teams are evaluating pyrovalve construction, historical leakage and inadvertent operation, electronic and software safety, and reliability of pyrovalves and controls. Pyrovalves and control systems for the Mars Science Laboratory have been a focus of this activity.

The Russian mini-research module, MRM-2 with Zarya FGB storage module in the foreground.

Review of MMOD Risk to the ISS Russian Mini-Research Module-2

Problem: The Russian Mini-Research Module-2 (MRM-2) on the International Space Station (ISS) does not meet the minimum requirement for the probability of no penetration (PNP) from micrometeoroids and orbital debris (MMOD). The United States (U.S.) and Russian MMOD communities agree on this fact but disagree on the risk of catastrophic failure due to an MMOD impact. The catastrophic risk assessment presented by the primary Russian ISS contractor, Korolev Rocket and Space Corporation Energia (RSC-E), was approximately one order of magnitude less than a corresponding estimate produced by NASA. Consequently, the ISS Program requested the NESC to perform an independent evaluation of the RSC-E and NASA risk assessments.

NESC Contribution: The NESC team reviewed the methodologies, assumptions, and processes used by both parties to derive their respective estimates of catastrophic risk. Members on the NESC team included individuals who helped create the application used by NASA to estimate catastrophic risk for the ISS.

Results: The team identified several possible sources of divergence between the two MMOD communities. During the assessment, subsequent risk calculations performed by RSC-E and NASA converged so that by the time the assessment concluded, the RSC-E estimate was roughly twice as high as the U.S. estimate, instead of a factor of ten.

Review of the AMS-02 Magnet Subsystem Replacement

Problem: The International Space Station (ISS) Program requested the NESC to independently evaluate the installation and operation of the Alpha Magnetic Spectrometer 2 instrument (AMS-02) on the ISS. This evaluation was to identify any previously unknown or unaddressed interface risks to the ISS, AMS-02, or the Space Shuttle (during AMS-02 launch and delivery in February 2011). Concerns arose because the AMS-02 instrument was to undergo a major reconfiguration (late in pre-launch integration and checkout) to replace the high-field-strength, cryogenically cooled electromagnet at the core of the instrument with a previously flown, lower-field-strength permanent magnet subsystem. The magnet design modification was necessary due to below-design-life projections for the cryogenic cooling system following integrated instrument thermal-vacuum testing.

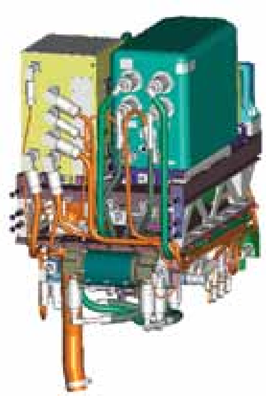
NESC Contribution: The NESC team reviewed the AMS-02 Project's thermal vacuum performance data and assessed the design alterations required to replace the cryogenically cooled electromagnet system with the permanent magnet. The team verified that the ISS and Space Shuttle Program integration teams had captured all of the delta requirements changes for Space Shuttle and ISS operations resulting from the magnet change out. The NESC team reported its findings to the ISS Program Manager, helping to clear the AMS-02 instrument for delivery to KSC for launch to ISS.

Results: The NESC team provided two recommendations to the ISS Program and the AMS-02 Integration Office: 1) provide a focused set of integration regression tests to verify the hardware, avionics, wiring, and other plumbing on the instrument still operated properly after the magnet change; and 2) review and approve revised analysis packages received from the instrument development consortium.

Technicians at KSC's Space Station Processing Facility move AMS-02 from a fixed stand to a rotation stand to begin processing for launch.

ISS Sabatier Assembly Operation Assessment

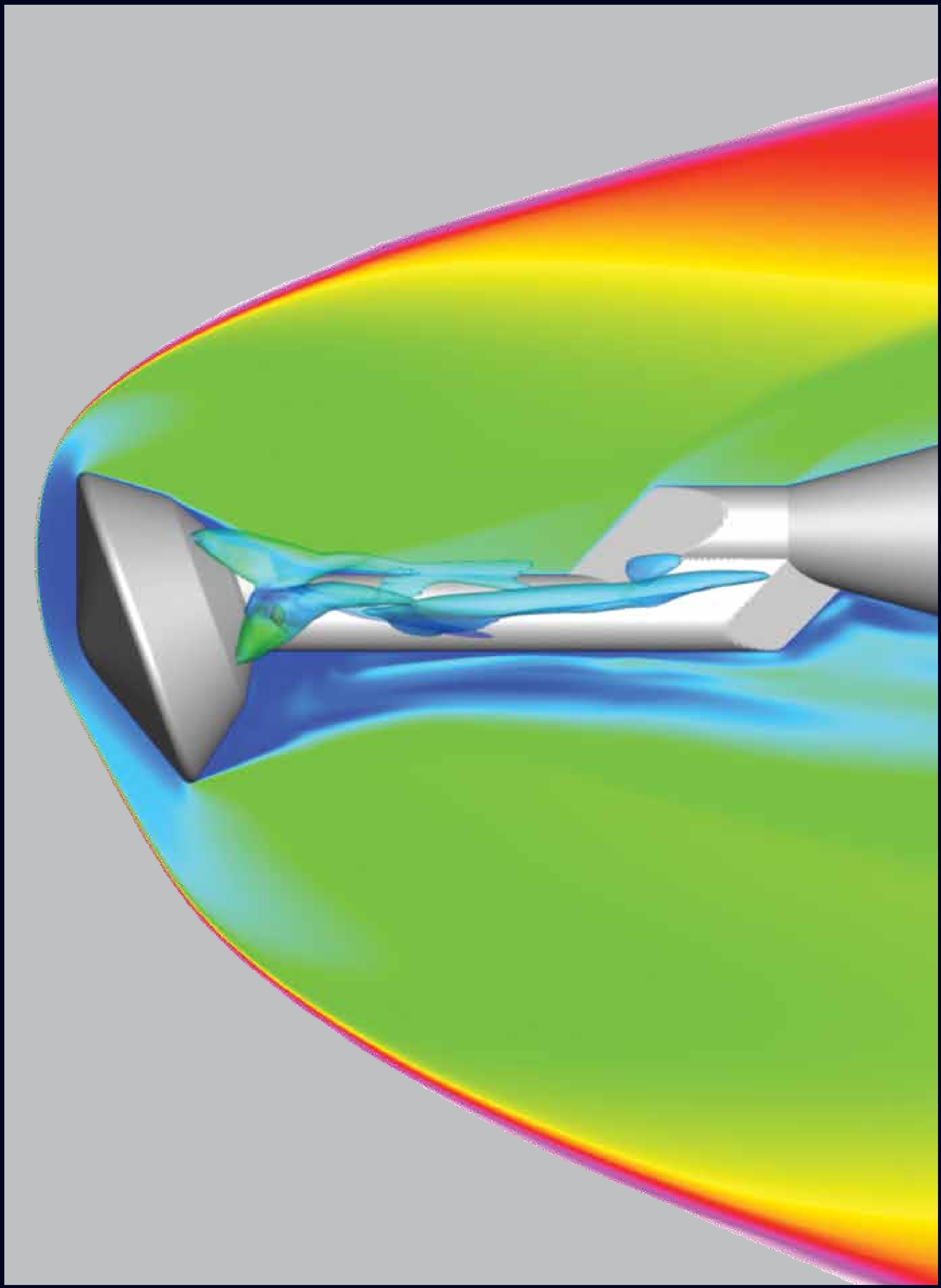
Problem: The International Space Station (ISS) Sabatier Assembly (SA) is a Hamilton Sundstrand design and an addition to ISS life support systems that produce water and recover oxygen from carbon dioxide (CO_2) exhaled by the crew. The Sabatier combines CO_2 from the Carbon Dioxide Removal Assembly (CDRA) with the hydrogen (H_2) gas from the Oxygen Generation System (OGS) to electrolyze water. The reaction at elevated temperatures creates water vapor and methane gas. The water is condensed and pumped from the water feed system to the OGS for electrolysis to produce oxygen (O_2) for crew consumption. The Sabatier process recovers about 50 percent of the O_2 that is consumed by the crew and partially closes the O_2 loop. There are risks of detonation in the H_2 feed lines and in the vent lines for the methane that is common to the OGS process.



The Sabatier Assembly combines carbon dioxide and hydrogen gas to produce water and methane gas. The methane is vented overboard while the water is used by the Oxygen Generation System to produce oxygen for the crew.

NESC Contribution: The SA has had more than 20 years of ground testing, and the CO_2 and H_2 reaction process is well understood. The NESC analyzed risks in the SA operation, controls, and safety. Risks to the crew from detonation of gases and the potential loss of the CDRA and OGS from standalone operation were also assessed.

Results: NESC verified that the firmware and software (SA and ISS) controls are adequate for normal operations and for safing the systems. Redundant sensors and indications of problems, inward leakage of O_2, and sensor limits to prevent detonation within the systems design are present. If detonation should occur there is containment to ensure no hazard to the crew. The SA reaction temperature is self-regulating so there is no risk of a runaway reaction. Prevention of failed "on" heaters is mitigated by redundant controls. Although structural design stress analysis shows containment of the shock pressure wave within the H_2 flex hose is unknown in a detonation scenario, the SA controls, detection limits, and shutdown logics are adequate to prevent detonation mixtures from occurring in the flex hoses. There is a low risk and probability of detonation in the methane vent valve because that requires two simultaneous failures in both SA and OGS within the first few seconds during SA startup. There is adequate ISS recovery time and spares to replace the vent valve, if necessary. NESC concurred with the activation of the SA on the ISS.



Computational fluid dynamics (CFD) solution of the Mars Science Laboratory during entry to Mars. The NESC sponsored a CFD model validation effort using data collected in the LaRC 31-Inch Mach 10 Wind Tunnel.

Earth Re-entry Observation of Hayabusa Sample Return Capsule

Problem: Hayabusa is a Japan Aerospace Exploration Agency (JAXA) mission that explored and retrieved sample material from a near-Earth asteroid and whose sample return capsule (SRC) re-entered the Earth's atmosphere over Australia on June 13, 2010. NASA has sparse entry, descent, and landing (EDL) data for super-orbital re-entry events. This re-entry provided a rare opportunity to acquire data from such an event. To take advantage of this opportunity, NASA initiated an observation project utilizing NASA's DC-8 airborne laboratory mounted with approximately 12 instruments to observe the re-entry event. This super-orbital re-entry observation effort was managed by ARC with observation flight objectives and methods similar to the Stardust SRC re-entry observation campaign in January 2006. A couple of key differences were that Hayabusa was not a NASA mission, and its SRC did not re-enter the Earth's atmosphere over United States airspace.

NESC Contribution: The NESC supported the Mission Readiness Review of the NASA component of this effort. The NESC team included subject matter experts from seven Centers, with experience and expertise in instrumentation, logistics, high-velocity atmospheric re-entry, and several NASA projects including both Stardust and the Hypersonic Thermodynamic Infrared Measurements (HYTHIRM) airborne observation projects. This team was assembled to review and assess the science objectives, approach, and methods of the airborne observation, and make recommendations, all to maximize the probability of success.

Results: On June 13, 2010, the NASA effort successfully observed the Hayabusa's SRC as it re-entered the Earth's atmosphere over Australia.

(Left) Greg Merkes of NASA Ames' video team operating an HDTV camera on board NASA's DC-8 airborne laboratory. (Above) Image of the capsule's successful re-entry over Australia and breakup of the spacecraft.

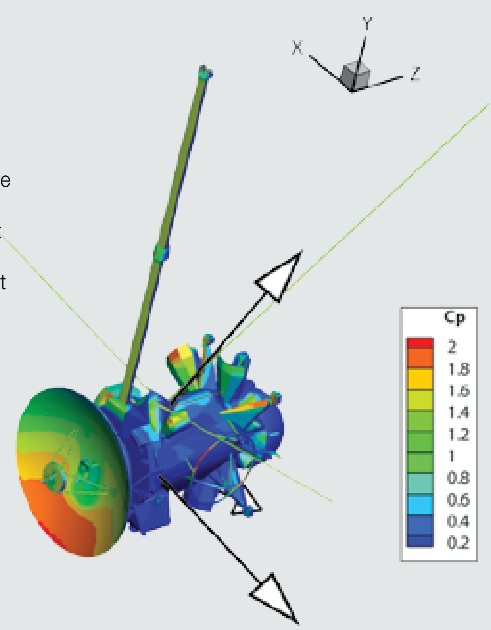
Review of the Cassini Flyby Parameters for Close Encounter of Titan

Problem: A top priority of the Cassini spacecraft's current Equinox mission is to determine if Saturn's moon Titan exhibits a magnetic field. To measure the magnetic field, the spacecraft must dip into the Titan atmosphere below the ionosphere and within 880 km (547 mi) of the surface, which is 70 km lower that any previous flyby. If the atmosphere is too thick during this low approach, then large aerodynamic torques could drive the spacecraft out of control or unanticipated heating could damage sensitive instruments.

NESC Contribution: The NESC team conducted an assessment of the Cassini Titan "T-70" flyby to predict the range of atmospheric characteristics, aerodynamic torques, and heating likely to be encountered by the spacecraft. In addition, the team recommended a spacecraft orientation that would minimize the aerodynamic torques and maximize the controllability (safety) margin during the closest approach. Thrusters would fire during the flyby to maintain the desired orientation.

Results: The NESC data, used in Cassini mission simulations, showed that the flyby would be within the desired safety margins when using the identified spacecraft orientation, thus allowing the mission team to go forward with the flyby. The flyby was successfully completed on June 21, 2010, where the spacecraft pointing was maintained within the predicted limits, and key data were obtained that will increase the scientific understanding of the evolution and interior of Titan.

Aerodynamic pressures and the resulting forces and moments were predicted on the Cassini spacecraft during the Titan flyby using a Direct Simulation Monte Carlo method.



Assessment of Wide-Range Pump on Sample Analysis at Mars Instrument

Problem: The Mars Science Lab (MSL), Sample Analysis at Mars (SAM) instrument, Wide-Range Pumps (WRP) are molecular-flow turbopumps designed to provide the "vacuum" that the SAM instruments need to pull helium and CO2 gas through the instrument sensors. Two WRPs on SAM are mounted on the center support plate and operate at 100,000 rpm. Due to anomalies during build-up and life testing, the NESC was asked to review the design, test history, performance, strengths, and weaknesses and provide recommendations to the Project.

Two Wide Range Pumps are used on the Sample Analysis at Mars instrument to provide vacuum that pulls helium and carbon dioxide gas through the instrument sensors.

NESC Contribution: The NESC gathered a team of experts in mechanism design and performed an assessment of the project's position and plan forward. The team consisted of mechanism design engineering authorities and analysts from multiple NASA Centers including GSFC, JPL, GRC, MSFC, and HQ, and their contractors.

NESC expert team members provided input on bearing configuration design changes and recommendations. These included reinforcing the decisions for retainer types that might prolong operational life. Team members performed previously omitted rotor dynamics analyses and confirmed the presence of a 30,000-rpm system resonance as well as another resonance slightly above 100,000 rpm. This modeling tool was used to evaluate potential modifications to the system that might reduce the effects from operating through resonance. The tool showed that given the envelope constraints, modification would not have a significant effect on performance; therefore, significant redesign would be required to change these characteristics.

The NESC team performed a bearing retainer stress analysis to model the source and progression of a cracked retainer. This analysis provided confidence in the most probable cause for the cracked retainers and illustrated the high-strength margins during nominal operations.

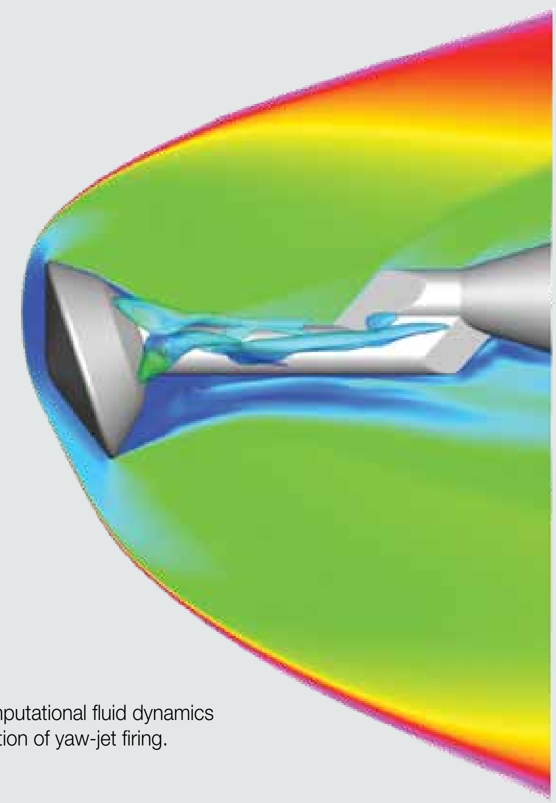
Results: The NESC's contributions were valuable to the Project by providing a better understanding of the system through analyses, conducting an independent evaluation of the pump assembly, and giving guidance to the Project for its path forward by experts in the industry. In many cases, the NESC's position provided the Project with reinforcement of its plan to acquire the resources needed to move forward with the least-risk posture. The NESC team worked with the SAM Project to produce a flight product that has high confidence for meeting the mission requirements.

MSL Aerodynamic Reaction Control System Interaction Model Validation

Problem: The Mars Science Laboratory (MSL) entry capsule will be using the first active control system flown at Mars since the Viking Lander. It is important to validate computational predictions of the interactions between aerodynamic flow over the vehicle and reaction control system (RCS) jet plumes to ensure the controller applies the intended torques.

NESC Contribution: The NESC is conducting an aerodynamic/RCS interaction test in the LaRC 31-Inch Mach 10 Wind Tunnel. Model force and moment measurements with cold-jets scaled to match MSL flight conditions will provide validation data for computational fluid dynamics (CFD) analyses. An earlier wind tunnel test was attempted by the MSL Project, but aerodynamic heating of the balance affected measurements resulting in no useful data. A key modification in the NESC test was the fabrication of a shield to completely cover the balance and flow-through sting that supplies nitrogen gas to the RCS jets. To compare to the experiment data, new CFD calculations are being run by ARC and LaRC for independent model validation.

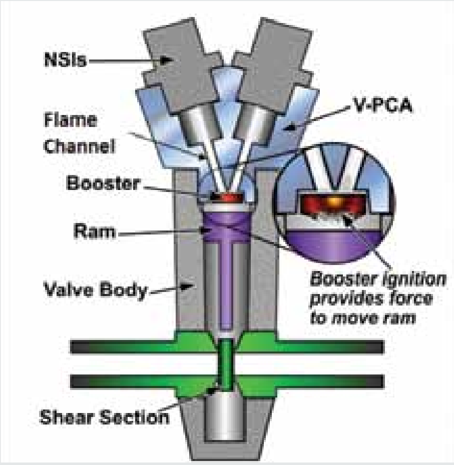
Results: Wind tunnel testing began in September 2010. Early indications show that the thermal effects have been almost completely eliminated. To date the test has collected extensive data for CFD model validation that will support MSL flight decisions.



Computational fluid dynamics solution of yaw-jet firing.

Study of Stainless Steel Pyrovalve Configurations and Firing Skew Timing

Problem: The Mars Science Laboratory (MSL) is using pyrovalves with stainless steel (SS) dual initiator, primer chamber assemblies (PCAs). A prior NESC study identified that a timing skew between firings of the initiators had a direct effect on the success or failure of the valve to operate as intended. The valve manufacturer developed a new design in an effort to minimize the effect of firing skew times. The new SS design uses a separate flow channel from each initiator forming a "V" shaped configuration (V-PCA). This appears to have solved several design shortcomings of the heritage aluminum PCA which has a "Y" shaped (Y-PCA) flow channel design. Statistically based testing was performed to quantify the improvement and provide data for the MSL and future applications. The NESC was requested to initiate a detailed, empirically based study to generate the desired reliability data.



Newly designed pyrovalve showing separate flame channels.

NESC Contribution: The NESC team measured the booster interface temperature and pressures for both the "V" and "Y" configurations. Additional testing is being performed to quantify the amount of command skew needed and characterize the larger flow channels.

Results: The SS V-PCA produced an average booster interface temperature of 2,300 °F versus 1,400 °F for the legacy aluminum design during single initiator firings. This demonstrated a greater SS V-PCA booster ignition margin. However, the SS V-PCA showed no improvement during simultaneous firings (skew less than 5 μs). Both PCA designs failed to produce a reliable ignition temperature. Additionally, doubling the diameter of the flow passages in the SS V-PCA (four times the cross-sectional area) did not eliminate the simultaneous firing anomaly. The NESC team recommended that firing commands be separated by at least 2 ms to guard against potential valve operational failure. NESC technical bulletins (TB) 10-02 and TB 09-01 provide additional information on this important issue and are available at nesc.nasa.gov.

WMAP Anomalous Battery Operations Investigation

Problem: The Wilkinson Microwave Anisotropy Probe (WMAP) encountered sudden and unexplained periodic step voltage drops beginning in August 2009 and extending through December 2009. These step voltage drops posed a significant risk to completing the extended mission. Left unchecked, the bus voltage was expected to drop below the level necessary to maintain operational capabilities by early 2010. GSFC Engineering requested assistance from the NESC to determine the source of the observed anomalous battery behavior and provide corrective action recommendations.

WMAP 23 amp-hr NiH2 common-pressure-vessel based flight battery during ground acceptance testing prior to launch.

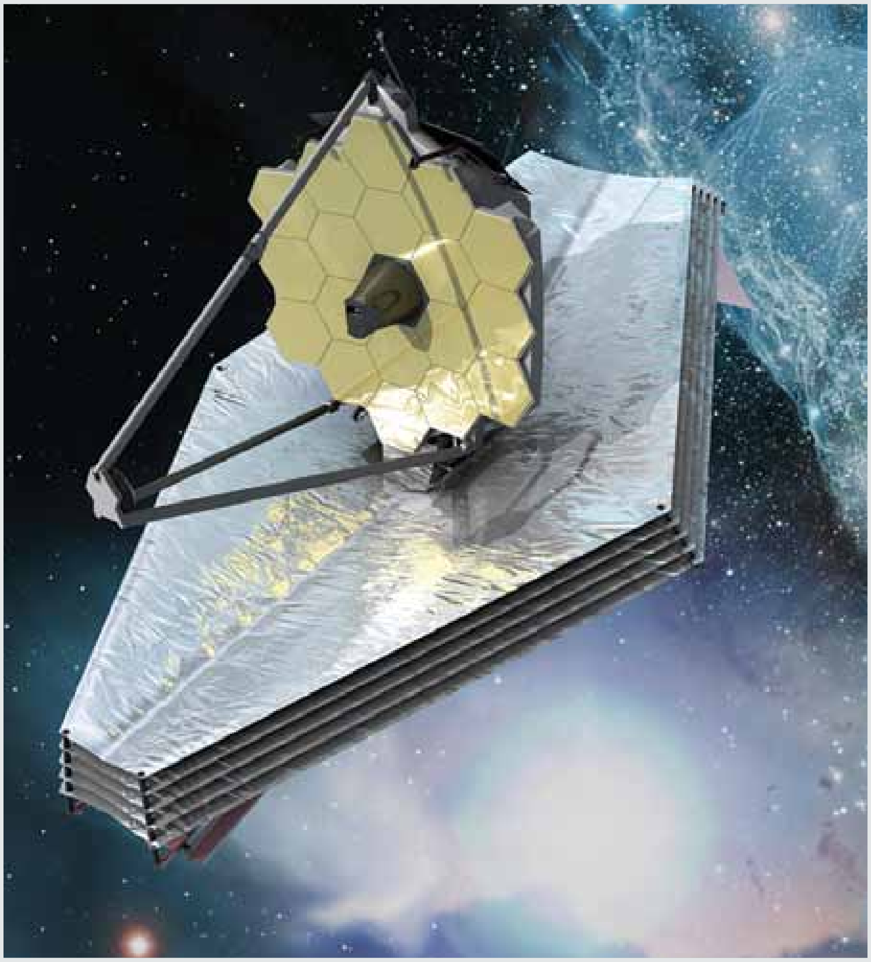
NESC Contribution: The NESC assembled a team of subject matter experts from across NASA, academia, and industry to examine the anomalous behavior and determine what corrective measures might be appropriate to stem the negative performance characteristics. The NESC team quickly identified critical accelerated ground testing of the WMAP flight spare battery needed to characterize the on-orbit performance and was able to successfully duplicate the voltage collapse signature displayed on-orbit, as well as potential causes attributed to the behavior.

Results: The NESC team identified a previously undetected characteristic associated with nickel-hydrogen common pressure vessel (CPV) battery cells that was most likely causing the problems exhibited. While age and other normal degradation effects were ultimately discounted as contributing to the phenomenon, internal voltage-driven electrolyte creep and subsequent establishment of bridging between the cells within the CPV were determined to likely be causing an ionic current flow that ultimately depleted the capacity of one of the two internal cells. The limited time available to address the issue could not provide a definitive finding of the theorized coupling; however, laboratory testing of an equivalent electrolytic bridge in a CPV confirmed comparable losses as those experienced on-orbit along with the observed voltage behavior. A comprehensive set of recommendations for maintaining the health of the remaining, and thus far unaffected, cells was provided to GSFC Engineering to address the degradation with the battery performance.

As a result of the recommendations, WMAP was able to successfully complete the planned mission operations without further battery degradation.

James Webb Space Telescope Sunshade Venting Analysis

Problem: The James Webb Space Telescope (JWST) will be launched on an Ariane rocket to the second LaGrange point in 2014. The telescope's solar heat gain is limited by a deployable sunshield composed of five 0.001-in. and 0.002-in. Kapton® membranes. The membranes are folded and restrained for launch, so trapped air must be vented during ascent to prevent overpressurization and damage. Analysis is the primary means used to verify that the maximum allowable pressure differences across the membranes (on the order of 0.005 lb/in^2 differential) are not exceeded. The NESC was asked to perform an independent assessment of the analytical methods that are being used to predict the JWST sunshield ascent pressures.



NESC Contribution: The NESC is currently assessing the JWST sunshield venting analysis methodology. As part of the assessment, the NESC identified a concern of Helmholtz instability (similar to a flapping flag). Axial venting along a slack membrane might cause instability that would increase stress at the membrane hold-down points. A scaled blowing test using prototypic membranes was performed to assess the membrane flapping potential during ascent.

Results: No instabilities were observed in the membranes at any time during the NESC test, demonstrating that Helmholtz instability during ascent is not an issue. The final NESC assessment product will be an engineering report that reviews the JWST Program's analysis approach, assumptions, and its relation to the results of the contractor's sectional sunshield vacuum venting tests.

Artist's concept of the JWST. The elongated hexagonal-shaped sunshades are extremely thin. The folded membranes must release air trapped between the layers as the telescope is launched from earth to the vacuum of space.

James Webb Space Telescope Cryocooler Disturbance Model Review

Problem: The James Webb Space Telescope (JWST) employs a mechanical cooler to condition the optical module and detectors of the mid-infrared instrument (MIRI) to 7 Kelvins or less. The performance degradation from ideal imaging, due to vibration sources (both pulsating from the mechanical pump and random from the cold gas) will be simulated by analysis with no plans to validate the models by testing. These cold gas force simulations use estimated forces from analyses that have not been thoroughly reviewed by independent subject matter experts in the relevant fields.

NESC Contribution: This assessment will provide an in-depth review of the Northrop Grumman (NG) analysis and disturbance models in determining if a credible risk exists with the operation of the cryocooler system on the MIRI detectors. The NESC team will conduct independent modeling and analysis to enhance the credibility of the overall JWST simulation results and, if possible, make recommendations for model validation tests.

Results: The NESC team has confirmed that the NG analysis of forced pulsating forces using the Sage model (analysis approach, assumptions, boundary conditions, and parameter sensitivities) is appropriate and provided conservative predictions of the resulting forces. The NESC team is performing computational fluid dynamics analyses to determine the forces generated by unsteady gas fluid dynamics interacting with the cryocooler complex geometry (valves, sharp turns, etc.). In order to independently estimate the attenuation of pulsating sources, distributed parameter impedance models of the coolant line will be constructed to determine the overall JWST flow-induced vibratory environment.

Time-Optimal Spacecraft Slewing GNC Technology Demonstration

Problem: Time-optimal attitude maneuvering is desirable for NASA mission applications in which the spacecraft is tasked with making several widely spaced science observations in a short period of time. Typically three-axis reaction wheel, or control moment gyro, controlled spacecraft use a well-established ‘eigenaxis trajectory’ technique for large angle attitude maneuvering. The eigenaxis trajectory is favored for attitude rotations because it is simple to implement in the spacecraft’s on-board flight software. This maneuvering technique accomplishes the desired attitude maneuver but in a non-optimized manner. In order to follow the eigenaxis trajectory, the spacecraft’s attitude control system must overcome inertial dynamics while remaining within the momentum and torque limits of the wheels. These constraints must be taken into account to optimize the maneuver so that the slew time is minimized.

NESC Contribution: The Transition Region and Coronal Explorer (TRACE) is a three-axis stabilized spacecraft that has steadily been pointing within 5 arcsec of the Sun since April, 1998. In July 2010 as part of the plan to decommission the TRACE spacecraft, GSFC solicited ideas for on-orbit experiments utilizing the spacecraft bus. The NESC Guidance, Navigation and Control (GNC) Technical Discipline Team (TDT) canvassed the GNC community of practice for possible experiments and responded with a GNC discipline advancing test concept. The Attitude Control System (ACS) engineer that originally designed the TRACE ACS was asked to review the feasibility and the merits of performing an on-orbit time-optimal slew experiment. There was technical agreement within the GNC community that having access to TRACE as an orbital test bed represented a unique high-payoff opportunity. Specifically it would allow demonstration of advanced control algorithms, developed by the Naval Postgraduate School (NPS) and C. S. Draper Laboratory (CSDL), for performing large-angle time-optimal spacecraft attitude slew maneuvers.

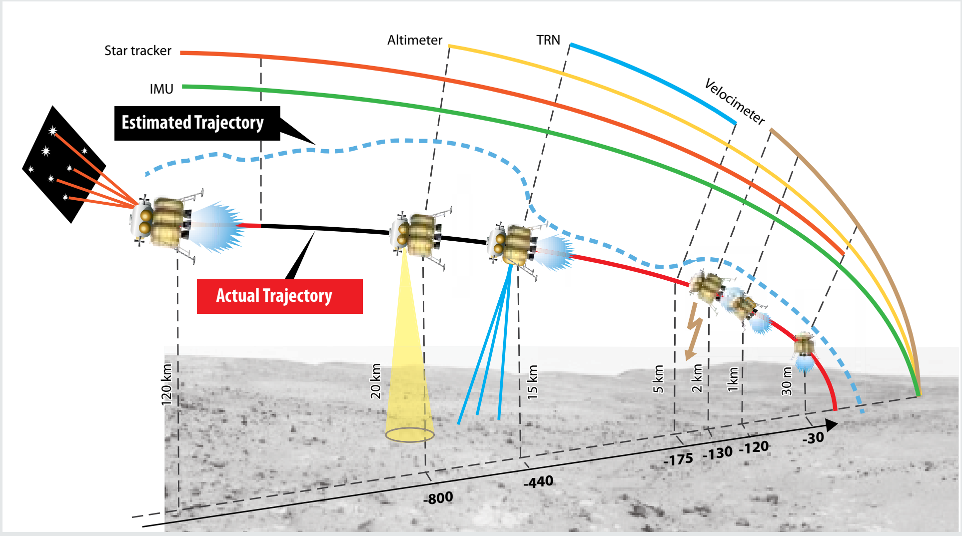
The objective of this on-orbit experiment was twofold: to establish the technical maturity of the optimal slew law algorithm and to demonstrate that the overall maneuver operational concept was low risk. Both NASA and the Air Force mission managers want to confidently perform similar optimal slew maneuvers on operational spacecraft. A collaborative effort was subsequently initiated involving the NPS, CSDL, the US Air Force (USAF), NESC, and the TRACE Flight Operations team at GSFC. The USAF agreed to sponsor engineering work by both CSDL and NPS to tailor their time-optimal attitude slew law for the TRACE demonstration. NESC’s technical participation, sponsorship and team coordination was instrumental in accomplishing this on-orbit GNC technology demonstration. In particular the NESC supported the GSFC TRACE Flight Operations and Flight Software teams in their effort to verify that the time-optimal slew maneuver could be safely implemented. The GNC TDT worked with the experimenters to define the demonstration and was part of the team that planned the schedule of events, particularly contingency plans for additional maneuver experiments to help resolve anomalies in the flight data.

Results: The TRACE flight demonstrations compared favorably with pre-test predicted performance. The time optimal maneuver demonstrated on TRACE minimized the transfer time between two attitude end states even though it normally is accomplished by traversing a greater angular distance than the eigenaxis maneuver. As it was implemented for demonstration on the TRACE spacecraft, the time optimal maneuver used special non-eigenaxis attitude trajectories to take advantage of the spacecraft’s nonlinear system dynamics. The maneuvers were executed by commanding the reaction wheel assembly controller with stored time-tagged commands that were pre-computed in ground software.

The TRACE demonstration significantly contributed to advancing the Technology Readiness Level of this optimal control technology. Future demonstrations on other spacecraft will include the use of on-board flight software to compute the time optimal attitude commands rather than pre-computing them using ground software and uploading them to the spacecraft.

Simulation Framework for Rapid Entry, Decent, and Landing Analysis

Problem: 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. Phase 2 of this activity extends the effort completed in Phase 1 by including additional models.



Attitude controllers, aerobraking managers, aero uncertainties and gravity models among others to extend successful EDL mission simulation capabilities are being developed to facilitate rapid prototyping of future missions. Illustration is of a Multimode Kalman Navigation filter model.

NESC Contribution: An NESC team converted and archived relevant EDL models and scripts into a secure user library with appropriate user documentation and test cases during Phase 1 of this activity. These models included mass and aerodynamic vehicle models, atmospheric and gravity models, and guidance and control algorithms. Phase 2 is providing additional new models not included in Phase 1: a multimode Kalman Navigation Filter for onboard state estimation, aerodynamic uncertainties for dispersion analyses, updated Earth environment models, additional guidance models for aerocapture and aerobraking, and several basic attitude-control models.

Results: 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. The inclusion of the additional models from Phase 2 will increase the types of systems and problems that the Agency can rapidly evaluate in systems analysis studies, preliminary design, mission development and execution. This will also reduce the response time for time-critical assessments.

COPV Life Prediction Model Development

Problem: Stress rupture of composite overwrapped pressure vessels (COPVs) is an insidious failure mode that can occur at normal operating pressures and temperatures resulting in a sudden COPV burst. Deficiencies were identified in the parameters and structure of stress rupture lifetime modeling approaches previously used. The objective of this work is to develop a validated life prediction model for stress rupture of COPVs.

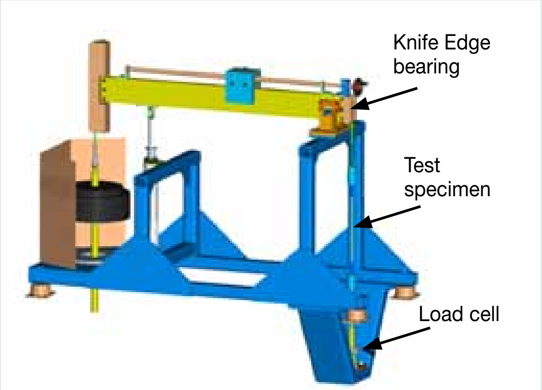


Illustration of the Design for Stress Rupture Test Fixture showing a composite strand under tension.

NESC Contribution: To address this problem, the NESC assembled a team of experts from JPL, LaRC, GRC, MSFC, JSC, and academia with backgrounds in composite modeling, statistical methods and uncertainty, reliability engineering, COPV fabrication, and strand testing. This team will develop an empirically based model including the effects of proof testing and uncertainty treatment.

Results: Analysis and testing will be conducted over several years and will involve testing of both composite strands and sub-scale vessels. During 2010, the NESC team worked with experts at Lawrence Livermore National Laboratory to design strand specimens, strand grips, and test rigs (shown in figure). Construction and testing of a prototype test rig is underway with work continuing on specimen design. Design of experiments principles are being used to plan efficient test matrices. After the comprehensive testing is completed, the NESC team will compile and document the strand and subscale COPV empirical data, reliability estimation models, findings and recommendations, and a list of underlying assumptions. Testing methods and lessons learned will be compiled along with any recommended follow-on testing.

Risk Reduction Testing of Field Programmable Gate Arrays Completed

Problem: Multiple NASA projects want to use the latest series of Actel RTAX-S Field-Programmable Gate Arrays (FPGAs). These parts offer significant advantages over the use of previous FPGA versions (RTSX-S or RTSX-SU) with regard to maintenance of signal integrity, capacity, capability, speed, and electrostatic discharge tolerance. Reported user application-related failures in the previous generation of FPGAs (RTSX-S) precipitated concerns late in the hardware-design cycle for several NASA projects, causing significant cost impacts and higher mission risks.

NESC Contribution: The NESC conducted a 6,000-hour test of 80 units (two lots) of RTAX250S and 80 units (two lots) of RTAX2000S programmed with an algorithm designed to emulate expected space flight applications. The test series subjected the parts to the voltage and temperature specification limit conditions. The selected representative space flight designs include multiple copies of a Military Specification 1553 Remote Terminal interface, an eight-bit microprocessor, Embedded Block Random Access Memory, an Error Detection and Correction algorithm, a Memory Controller, and a Universal Asynchronous Receiver/Transmitter.

Circuit board using multiple RTAX2000S parts.

Results: Following completion of the planned 6,000-hour test in the second quarter of calendar year 2009, the results indicated no part failures or part "out of specification" conditions. These results were formally documented and distributed to Agency and industry RTAX users.

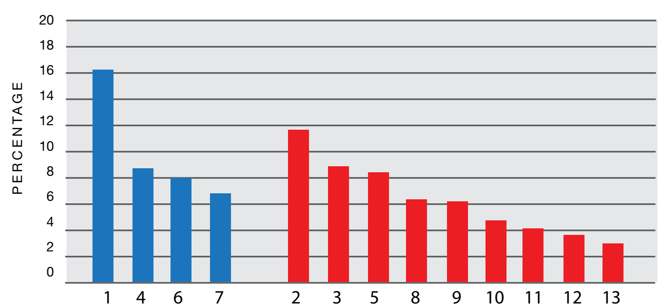
Improving Spacecraft Connector Selection and Application Processes

Problem: The Agency has experienced high-profile connector problems, the most recent and publicized of which being issues with the Space Shuttle's main engine, low-level liquid hydrogen cutoff system (specifically the cryogenic feed-through connector). This problem had similarities to an Atlas expendable launch vehicle issue experienced and resolved some years earlier. This issue and similar occurrences pointed to the need for a broader Agency review of the electrical connector selection and application processes for space flight use, and how lessons learned and past problem records are fed into new programs to avoid recurrences.

NESC Contribution: An NESC team, which included members from all Centers, reviewed spacecraft electrical connector selection and application processes on various ongoing projects. This included reviewing how lessons learned are incorporated and disseminated. It is noteworthy that these knowledge-transfer processes fail to share lessons learned with potential commercial partners. Each Center's controlling documentation for spacecraft connector selection and application, including the roles of Government and contractors, was also examined. In December 2008, the team participated in a Government Inter-Agency Science and Technology Wiring Working Group Meeting and surveyed the Society of Automotive Engineers Connector Committee members regarding their experience relative to NASA connector concerns. For this assessment, the NESC team attempted to determine whether spacecraft electrical connector selection and application processes could be improved.

Results: While the number of documented operational failures is not large when the scope of use is considered, the majority of spacecraft electrical connector issues are application related and tend to reoccur with potentially serious consequences to mission success and safety. Connector failures occur throughout the life-cycle (from design to field usage), but data analysis suggests that the majority of connector issues are application related. The team recommended several targeted adjustments to improve the effectiveness of the existing Agency Lessons Learned Information System and technical community knowledge transfer.

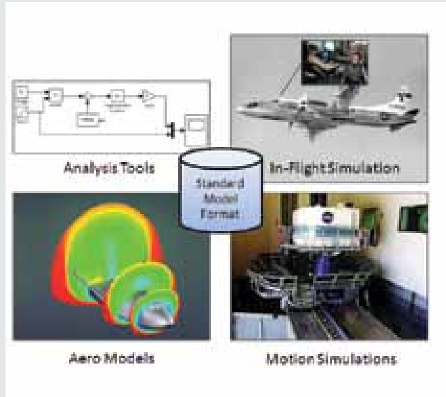
Failure mode distribution of connector faults and failures encountered at GSFC. The four blue bars on the left are workmanship-related; the red bars on the right are other modes.



1- Missing or incorrect hardware; 4 - Incorrect wiring; 6 - Other OEM workmanship; 7-Assy interference; 2-Damaged or failed; 3-Loose; 5- Not seated/mis-mated; 8- Broken wire/conn; 9- Elec. short; 10- Corrosion/contamination; 11- Elec. open; 12- Misaligned, 13- Bent pins/connector

High-Fidelity Flight Simulation Model Exchange Framework Developed

Problem: Almost every NASA Center has at least one flight simulation facility and utilizes a variety of analysis tools. These are, in general, independently developed, high-fidelity flight models tailored for one facility or tool, and are often incompatible with other facilities and tools, even within the same Center. Sharing models frequently requires extensive manual effort rewriting source code to "rehost" a simulation model in a new environment.



A common format for Flight models can facilitate rapid implementation.

NESC Contribution: A multi-Center NESC team was assembled to examine a new method to make models more easily interchangeable. The team examined a draft American Institute of Aeronautics and Astronautics (AIAA) standard that attempts to address this problem through use of a custom Extensible Markup Language (XML) grammar to encode high-fidelity flight simulation models. Each participating Center developed a means to automatically import and validate such formatted XML models in their real-time simulation framework and provided feedback to improve the standard and application in NASA facilities.

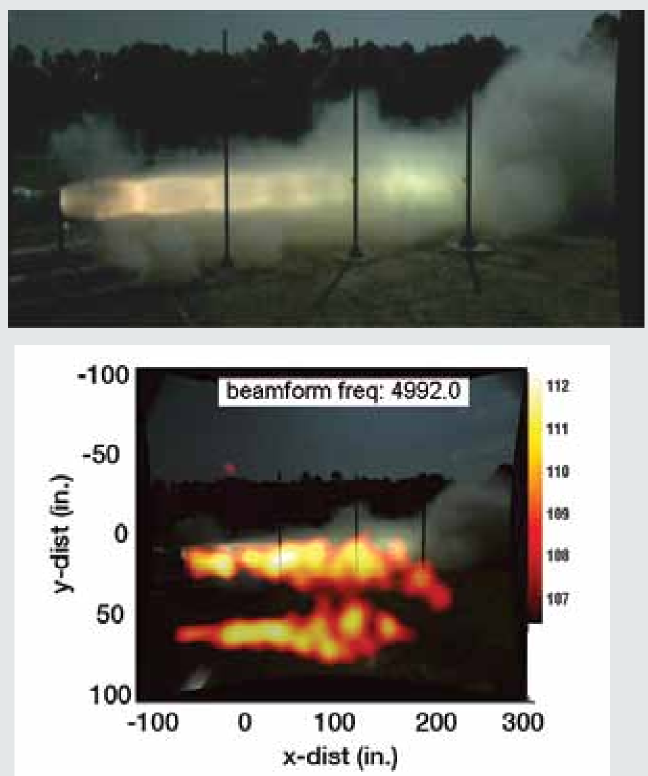
Results: Each Center was successful in importing and rehosting the example simulation, a lifting-body reentry vehicle, into their real-time simulation framework. By leveraging software libraries developed both internal and external to NASA, several team members were able to complete the rehost in less than a week. Several suggestions for improvements in the standard were forwarded to the Modeling and Simulation Technical Committee of the AIAA. A final recommendation regarding adopting this AIAA standard within NASA is pending.

Microphone Phased-Array for Measuring Liftoff Acoustics

Problem: The high vibroacoustic environment created during liftoff can pose a significant threat to payload, avionics, and other critical systems of a launch vehicle. Abatement schemes (e.g., water injection, passing engine exhaust plumes through trenches, etc.) can be optimized if knowledge of noise source distribution becomes readily available. Currently, there is no direct means of identifying acoustic sources during launch vehicle liftoff.

NESC Contribution: A microphone phased-array is an emerging technology that uses many microphones and beam-forming algorithms to isolate and identify acoustic sources. It is extensively used in aircraft design but has not found its way into spacecraft applications. The current assessment's objectives are to ruggedize the array hardware for use in harsh launch environments and demonstrate its usefulness in a series of progressively more aggressive engine firing/launch environments.

Results: An environment chamber was designed and built to protect an existing microphone phased-array for the initial series of tests. The initial exposure involved exposure to a solid rocket motor fired in a horizontal test stand. The planned follow-on testing involves a vertically mounted, 5-percent–scaled model of the Ares I launch vehicle. Review of the initial test series showed comprehensive data collection. The resulting source maps represent the first known application of a microphone phased-array to characterize rocket engine plume environments. Future plans involve additional measurements of solid and liquid engine firings to determine which measurement systems require hardening to the increasingly more aggressive environments.



Solid rocket plume (top) and an acoustic energy image (bottom) showing the noise source distribution at indicated frequency. The double plume in the acoustic image is due to the reflection on the concrete floor which acted as an acoustic mirror.

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 the Constellation Program's Ares I and Ares V 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 a large-scale test capability, the first series of large-scale buckling test articles, programmatic and technical support, peer reviews, and advocacy.

Results: In 2010, the SBKF Project made significant progress in several key work areas including sub-component and component testing and analysis of aluminum-lithium (Al-Li) and composite panel concepts, Ares V structures trade studies and associated mass savings estimates, and testing of an alternate Al-Li alloy 2050 for the Ares V core stage. Some of the highlights include successful testing of two additional 8-ft diameter, Al-Li orthogrid-stiffened barrel test articles. These test articles were 45-percent–scale versions of an Ares I upper stage liquid hydrogen barrel design, and were predicted to exhibit several important behavioral characteristics including longitudinal-weld land buckling and stiffener crippling. The high-fidelity analysis predictions of these scale tests continue to correlate well with the test results and, once validated, will become the basis of refined analysis-based design factors.

In addition to the SBKF development efforts on Al-Li–stiffened cylinders, this activity is considering fiber-reinforced composite cylinders. The central goal of this composites effort is to examine how the refined buckling recommendations can be applied to composite cylinders. Experimental and analytical studies are underway to meet this goal. Industry partners are providing 8-ft and 13-ft diameter composite cylinders for buckling tests. The 8-ft diameter cylinder has an out-of-autoclave sandwich composite construction, and the 13-ft diameter cylinder has an autoclave-cured, flute core-composite construction. Both cylinders have been designed, and building-block experimental testing and analysis are underway.

The SBKF Project plan includes fabrication and testing of two 27.5-ft diameter orthogrid-stiffened barrels in the Loads Introduction Structure (LIS) under development at MSFC. 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 will be instrumented with over 700 individual strain and displacement sensors, and low-speed and high-speed video image correlation systems will be used to obtain full-field displacement and strain measurements during the pre-buckling, transient-buckling, and post-buckling test phases. To this end, Space Shuttle Program External Tank-derived Test Article (ETTA) barrels have been designed and fabricated. Instrumentation has been installed on the first ETTA and testing will begin in February 2011.

External Tank-derived Test Article 1 in the process of having the final barrel panel welded using the Vertical Weld Tool at MSFC. Each 27.5-foot-diameter by 20-ft-tall barrel is made up of eight individual orthogrid barrel panels and were obtained from the Space Shuttle External Tank Project.

Lower load introduction structure (LIS) in the Loads Test Annex facility at MSFC in preparation for External-Tank-derived Test Article testing (ETTA1).

International Students Assist Shell Buckling Project

This past summer semester, the principal investigator for the Shell Buckling Knockdown Factor (SBKF) Project took advantage of the National Institute of Aerospace (NIA) Visitors Program to sponsor four international engineering students. The NIA's Visitor Program facilitates research collaborations between scientists and engineers at the NIA, the NASA Langley Research Center, researchers and academia. The SKBF Project interns were Masters and Ph.D. level students and responsible for structural analysis and testing. The students split their efforts between several tasks. In one task two students worked as a team to develop, verify, and implement a unique piece of testing hardware to help the Project assess the effects of small geometric perturbations on the buckling response of thin-walled, buckling-critical shells. In another task a student conducted a series of high-fidelity buckling analyses of imperfect composite and metallic shells to determine the effects of geometric and loading imperfections on the buckling of shells. In the last task the student studied the impact behavior of laminated composite plates and shells to determine the effects of impact energy, boundary conditions and panel curvature on the force, displacement, strain, and damage response.

Dr. Mark Hillburger (left) discusses shell buckling testing with international students (sitting, left) Benedikt Kriegesmann from Leibniz Universitaet, Hanover, Germany and (sitting, right) Massimiliano (Max) Bogge, (standing) Maria Elisa Palena, and Marco Maspoli, all from Politechnic University of Torino, Italy.

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 non-traditional 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.

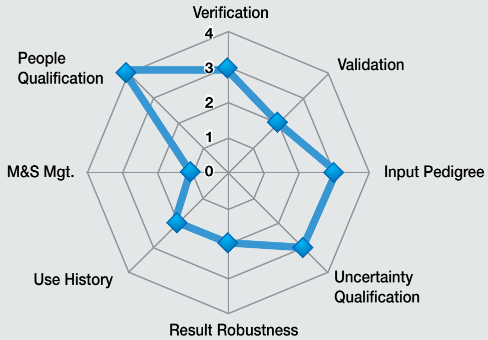
NESC Contribution: An NESC team is developing the capability to move the ground-based daily aerobraking maneuver processes onboard the spacecraft. These on-board processes include an ephemeris (orbital position) estimator, atmospheric density modeling, thermal modeling of the critical spacecraft elements, and maneuver strategy logic to keep the spacecraft safe and provide for the proper final orbital insertion.

Results: Simulations and analysis conducted during Phase 1 development will evaluate the viability of using autonomous aerobraking at Mars, Titan, and Venus. Pending favorable results, follow-on phases could ultimately include incorporating autonomous aerobraking on a future spacecraft mission for flight evaluation in a "shadow mode." The shadow mode evaluation would compare calculated on-board autonomous aerobraking commands 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.

Guidelines Developed for Models and Simulations

Problem: The NASA Standard for Models and Simulations (M&S), was a standard developed in response to Columbia Accident Investigation Board recommendations. Agency programs and projects have been slow to adopt the standard, in part because the document was necessarily written at a high level. NASA-STD-7009 is in its basic revision and is the first document of its kind within NASA, or industry. It applies to all types of M&S applications and all project life-cycle phases. Numerous requests have been received for clarifying the intended implementation approaches for the various topics in NASA-STD-7009, including the M&S risk and credibility assessment, two of the key features of the standard.

NESC Contribution: An NESC team containing subject matter experts from multiple Centers has developed a checklist and associated guidelines to enable programs and projects to effectively implement NASA-STD-7009 in a value-added manner. These products were also designed to assist NASA with the NASA-STD-7009 transition from a voluntary to a mandatory standard.



Example of a tool used in assessing model or simulation credibility.

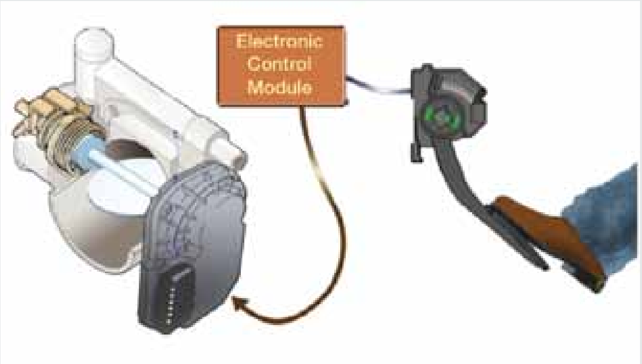
Results: Many personnel affected by NASA-STD-7009 will benefit from the development of implementation guidelines and tools. These personnel include M&S tool developers and operators, systems analysts, decision-makers using M&S analysis results, and independent reviewers of M&S products. The team's products include a checklist and guidelines for M&S reviews, changes to NESC procedures designed to reinforce NASA-STD-7009 concepts and requirements through independent assessments, and initial discipline-specific recommended practice guidelines.

NASA Supports NHTSA Investigation

Problem: In March 2010, the NESC met with personnel from the United States Department of Transportation (DOT)'s National Highway Traffic Safety Administration (NHTSA) to discuss possible causes of unintended accelerations in vehicles equipped with electronic throttle controls.

NESC Contribution: With NHTSA funding, the NESC forming a multi-Center team to work with NHTSA in reviewing the throttle control design for vulnerabilities that could possibly cause unintended accelerations. The team has participants from ARC, DFRC, GSFC, JSC, JPL, KSC, LaRC, and MSFC and includes experts in systems engineering, electrical engineering, software engineering, human factors, and electromagnetic compatibility. The overall goals of the study are to determine what specific conditions, both internal and external, are necessary for the electronic throttle control to fail; evaluate whether those conditions, if any, are evident in the reported consumer complaints; evaluate whether there is physical or electronic evidence left by the failure; determine the expected ranges in severity and duration that could be caused by the failure; evaluate whether the failure could have any effect on other interfaces, such as the braking system; and determine what data, if any, are sent to and captured by the event data recorder and the electronic control module.

Results: The NESC team is using a well-characterized systematic approach to study the electronic throttle control. The process began with a review of NHTSA's complaint database for information that might direct the investigation. Then the team is developing system and software functional diagrams to document how the design is intended to work. Functional failure modes, fault fishbone diagrams, event sequence diagrams, and fault trees are developed, based on literature from the manufacturer and testing on both electronic throttle control simulators and vehicles of interest.



Components of an electronic throttle control which translate pedal position into throttle body opening.

Ultimately, a test program was defined to verify any identified vulnerabilities. Once confirmed, the various categories of vulnerabilities (e.g., traceable to consumer complaints, warranty data, or field inspections) are being characterized as findings. Those vulnerabilities that cannot be substantiated by evidence are being categorized as observations.

NASA Continues Effort to Expand Data Mining and Trending

Problem: The Agency requires an improved capability to trend technical issues encountered in NASA programs and projects.

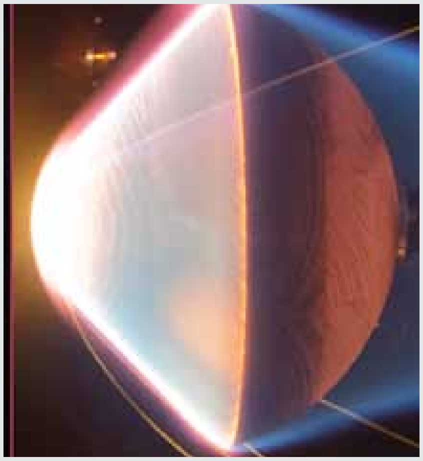
NESC Contribution: The NESC is leading an Agency-level Data Mining and Trending Working Group (DMTWG) whose purpose is to assist in the formulation and implementation of capability to strengthen trending of NASA programs and projects and to ensure appropriate visibility of data mining and trending. Through workshops, monthly meetings, and training, the NESC has developed working relationships with data mining and statistical experts within other government agencies, academia, and industry.

Results: The DMTWG is assisting NASA organizations by providing data-mining expertise to relevant NESC assessments, such as a request for special study from the National Highway Traffic Safety Administration to investigate reports of unintended acceleration in certain vehicles. DMTWG sponsored a faculty-student team for a 10-week internship at KSC. The team explored data-mining methodologies, focusing on open-source tools and in-situ database tools, as well as broadening the exposure of data-mining practices at KSC. 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.

Dr. Salamah Salamah (left), Embry-Riddle Aeronautical University, and Embry-Riddle student William White explored Data Mining and Trending during a 10-week internship at KSC.

Development of a NASA Thermal Performance Database

Problem: The Agency has no central database for thermal performance test results and analyses from flight projects. Thermal performance testing and analysis costs represent a significant Agency investment, but the data from prior missions are often difficult or impossible to access. As a result, decision makers frequently find it difficult to effectively use available data to draw valid conclusions. Data from previous missions are being lost as elements are misplaced, technical experts move on to other projects, and file formats become obsolete.



Testing of a large-scale article in the Ames Arc Jet facility. Data captured from test like these are a cornerstone of the database.

NESC Contribution: In 2010, the NESC completed preliminary systems engineering and began prototype development of a database to collect and store thermal performance test data (arc jet, radiant, solar, laser, etc.) including test results, calibration records, article configurations, facility operating parameters, and analyses. This effort produced an information architecture, framework trade study, system requirements, and a concept of operations. An operational prototype was developed to validate the schema and facilitate co-development within the user community. Data from ongoing missions such as Mars Science Laboratory and Constellation Program Crew Exploration Vehicle were archived, and a plan to collect historical data was developed.

Results: The NESC will provide an operational database accessible by Agency stakeholders by the end of 2011. The database will accept data from facilities, engineers, principal investigators, and analysts, and allow users to search for holdings based on user-specified criteria. A follow on task will collect, digitize, and input historical data using a discipline-based priority plan. During 2012, development will be completed and database operations will be transferred to Agency arc jet facilities for management and maintenance.

Development of a NASA Fault Management Practitioners Handbook

Problem: Fault management (FM) systems are employed in virtually all NASA space vehicles and ground systems. A FM system contains, prevents, detects, isolates, diagnoses, responds to, and recovers from conditions that interfere with nominal mission operations. This FM capability is known by other names across NASA, including Safe Hold Mode, Vehicle Health Management, Integrated Diagnostics, Prognostics and Health Management, Fault Detection, Isolation and Recovery, and Redundancy Management. During the past several decades, engineers working on NASA's robotic and human spaceflight programs have developed methods for fault mitigation, fault analysis, and contingency operations. In-flight FM system performance has generally been successful. However, the design and development of FM systems have sometimes stressed NASA's programmatic and engineering resources. Flight projects have suffered from unexpected cost growth and schedule slips during final FM system integration and test. It is apparent that reliable and affordable FM systems are not constrained by technology but rather by a lack of systematic engineering and programmatic discipline. The Agency currently lacks overarching conceptual guidance for architecting and implementing FM systems in spacecraft and ground systems.

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

NESC Contribution: The NESC, in collaboration with JPL, is developing a NASA FM practitioners handbook to provide overarching conceptual engineering guidelines and recommended best practices. One objective of the handbook is to collect the FM engineering practices used across NASA for both robotic and human spaceflight system development. It will serve as a reference for NASA discipline engineers, systems engineers, and project managers who are architecting, designing, and developing FM systems.

Results: The initial draft NASA FM Handbook was issued in September 2010, with an updated version of the handbook planned for early 2011.

President Obama and NASA Administrator Charles Bolden (far right) congratulate the NASA team (four leftmost) and the US drilling team.

NESC Support to the Rescue of Trapped Chilean Miners

Problem: On August 5, 2010, the San José copper and gold mine in Chile's Atacama Desert collapsed trapping 33 miners. After 17 days of searching, the miners were discovered alive approximately 2200 feet below the mine entrance. A rescue operation was initiated by the Chilean government that would lower a capsule to the miners through a newly bored hole, but not for over two months. The Chilean Government requested NASA's support because of its training and planning for emergencies in human spaceflight, and its protection of humans in the hostile environment of space.

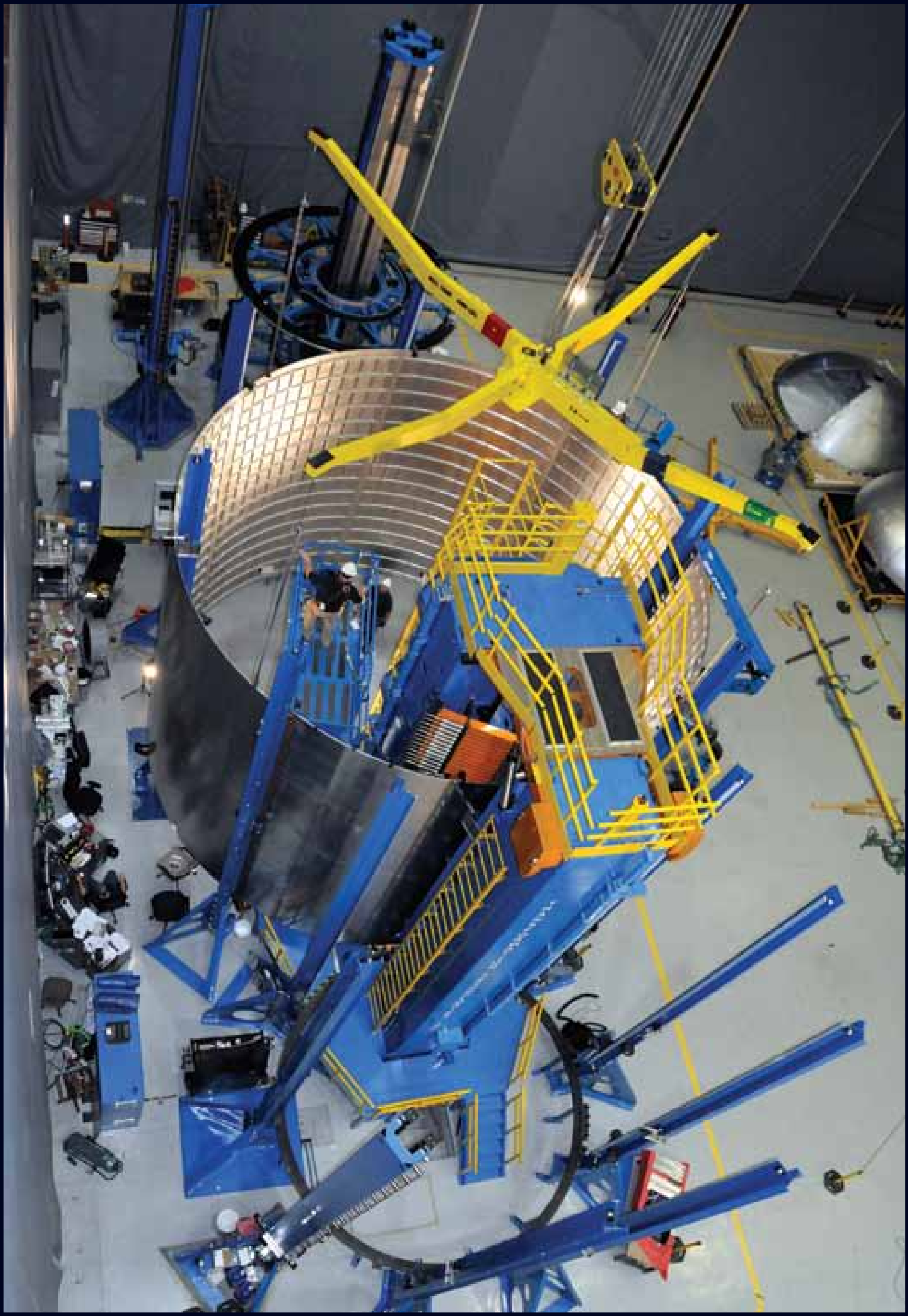
NESC Contribution: An engineer from the NESC's Principal Engineers Office participated in a four-person NASA team lead by the deputy chief medical officer at JSC. The NESC also participated in an Agency-wide brainstorming session to identify ways to assist the rescuers. As the operation was being formulated, recommendations were made in areas of air and water supply, hygiene, communications, bedding, and supply chain modeling. Additional medical advice was provided at the mine site for the men trapped below as well as organizational advice for the rescue operations at the surface.

NESC personnel also led a team which, in three days, developed and documented more than 50 design requirements for the capsule to ensure the safety and health of the miners as they ascended. The overall NESC group included the NASA medical team, the NASA Technical Fellows and members of their Technical Discipline Teams and NESC systems engineers.

Reuters/Chilean Government

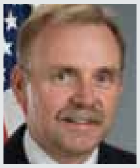
The NESC contributed design expertise to the Chilean government during development of the rescue capsule.

Results: The Chilean Government indicated that most of the suggested requirements were incorporated in the final design of the rescue system, which was built by the Chilean Navy. The rescue system components included the rescue capsule, the hoist system, communication devices and the miner's protective gear.



An External Tank-derived Test Article 1 for the NESC Shell Buckling Project in the process of having the final barrel panel welded using the Vertical Weld Tool at MSFC.

During 2010, Ames Research Center (ARC) continued to provide a wide variety of expertise to NESC activities. Approximately 32 scientists and engineers provided support to the NESC over a range of disciplines including human factors, wireless avionics, digital archives, composites, reentry systems, aerodynamics, non destructive evaluation, wind tunnel testing, software evaluation, and flight dynamics. The NASA Technical fellow for Human Factors is resident at ARC.



Nans Kunz
NESC's Chief Engineer at ARC

Exploration Systems

Wireless Connections in Space (WCIS): ARC supported the multi-Center NESC Wireless Connections in Space Project to develop and demonstrate a highly reliable wireless architecture capable of being implemented in radiation tolerant devices. The team developed and evaluated new wireless sensor network (WSN) technology based on the ZigBee Framework and IEEE 802.15.4 Personal Area Network (PAN) standard. The robustness of WSNs were experimentally evaluated in the laboratory including assessing this technology for space vehicle, sensing within enclosed metal volumes. Preliminary evaluations were favorable and further evaluation may lead to certification for flight.

Entry, Descent, and Landing (EDL): In 2010, the NESC completed preliminary systems engineering and began prototype development of an Agency database to collect and store thermal performance test data (arc jet, radiant, solar, laser, etc.) and related analyses. ARC led the archiving of data from the Mars Science Laboratory and Constellation Program Crew Exploration Vehicle activities into the prototype database developed at JPL, and developed a plan to collect and prioritize other historical data. An operational database accessible by Agency stakeholders will be complete by the end of 2011, with operations to be handed over to Agency arc jet facilities in 2012.

In another EDL related activity, the NESC sponsored the Mission Readiness Review of the successful Hayabusa Re-Entry Observation Project based at ARC. A review team that included people from seven NASA Centers with expertise in instrumentation, logistics, high velocity atmospheric re-entry and a breadth of NASA projects including both Stardust & HYTHIRM airborne observation projects, was assembled to review and assess the science objectives, approach, and methods of the airborne observation, and made recommendations for the purpose of maximizing the probability of success.

Orion Project Launch Abort Vehicle Stability Augmentation: Due to concerns that the Orion Project's Launch Abort Vehicle concept may not be able to maintain vehicle stability in certain flight regimes, the NESC is investigating the aerodynamic performance, design issues, and benefits of installing grid fins to enhance vehicle stability. As part of this investigation, the grid fins concept was tested in the ARC 11 by 11 and 9 by 7 foot wind tunnels.

Microphone Phased Array for Measuring Launch Vehicle Lift-off Acoustics: A microphone phased-array is an emerging technology that uses a large number of microphones and beam forming algorithms to identify noise sources. A microphone array developed at ARC was used during firing of a solid rocket motor in a horizontal test stand. Good data was collected from the test and the resulting source maps represent the first ever application of an array to measure a rocket plume.

Science

Stratospheric Observatory for Infrared Astronomy (SOFIA): This year, the SOFIA open port cavity shear layer control system that was developed at ARC (also the subject of a previous NESC assessment) successfully completed flight testing of the entire flight envelope. Key participants of the cavity test efforts from ARC briefed the NESC Loads & Dynamics TDT about the results including vibroacoustic environment and the dynamic response.

General

In support of the Department of Transportation National Highway Traffic Safety Administration (NHTSA) the NESC investigated software states that may cause uncommanded accelerations in vehicles with electronic throttle controls. The NESC team modeled the vehicle software to analyze the electronic throttle control, cruise control, idle speed control, vehicle stability control and diagnostic software modules. Both commercially available and ARC developed software tools were used to perform this analysis.

(Top) SOFIA 747SP flying observatory, shown with its infrared telescope visible, successfully completed testing of the entire flight envelope. (Bottom) Jarren Baldwin is seen testing WCIS prototype hardware.

(From Left) Dr. Lance Richards, Allen Parker, Anthony Piazza, and Dr. Hon "Patrick" Chan of the Advanced Structures and Measurement Technology Group prepare the NASA-developed fiber optic strain measurement equipment used on the CCM structure failure tests at LaRC.

Brad Flick (left), Director of Research and Engineering, and Michael Delaney, an NESC team member for DDT&E, discuss risk mitigations for PLD usage.

Mark Davis (left) the DFRC Deputy of the Flight Mechanics TDT discusses with Dr. James Stewart how his NESC experience helped him better support NASA's successful Pad Abort 1 test. The crew module was prepared for integration by DRFC.

Dryden Flight Research Center (DFRC) engineers have contributed to the NESC's multi-disciplinary teams in addressing the Agency's most challenging problems. DFRC engineers supported the NESC's Nondestructive Evaluation Technical Discipline Team (TDT) in structural testing of NESC's full-scale composite crew module (CCM). Over 15 scientists and engineers were involved in these activities. DFRC engineers supported the Guidance, Navigation and Control (GNC) TDT by starting a collection of common control tools used by GNC engineers. DFRC engineers and contractors participated in a number of NESC technical assessments. In addition, a DFRC engineer was assigned as the Deputy of the Flight Mechanics TDT and participated in four NESC Ares-1X assessments.

Dr. James Stewart
NESC's Chief Engineer at DFRC

Exploration Systems

DFRC engineers successfully supported structural testing of the NESC's full-scale CCM by installing NASA-developed fiber-optic sensors along the windows and docking port to monitor real-time structural strains. Each optical fiber contains hundreds of strain sensors. These sensors successfully monitored internal pressure load testing of the CCM in real-time. The final test subjected the CCM to structural failure, where the fiber optics system was able to withstand this aggressive environment and returned valuable data to assist in post-test analyses.

Space Operations

DFRC engineering supported the technical assessment and reporting of the development, design, test and evaluation (DDT&E) process for Robustness of Space Flight Programmable Logic Devices (PLDs). This system's level investigation was a combined hardware and software assessment that needed to be evaluated from a system perspective.

General

DFRC engineers supported the GNC TDT, including initiating a task to collect control system design and analysis tools that are used at the different NASA Centers. This collection of tools will allow rapid development and analysis of a given controller and will help educate and train control engineers in designing, testing, and evaluating control systems. This will also enable control engineers to understand how different NASA Centers have designed, tested, and evaluated their control system. The DFRC-based Deputy of the Flight Mechanics TDT assisted in generating the Flight Mechanics community of practice operational plan, and participated in four Constellation Program Ares I-X technical assessments. His experience as Deputy not only allowed him to see how the TDTs work, but he gained insight into how the NESC works with NASA as a whole. This experience was invaluable for his support of the CxP Pad Abort Flight Test.

During 2010, over 45 Glenn Research Center (GRC) engineers, scientists, and technicians provided a broad range of unique skills to NESC assessments, NESC Technical Discipline Teams (TDTs), and special projects.

Richard Manella
NESC's Chief Engineer at GRC

Exploration Systems

GRC was involved with an NESC assessment to assure NASA is performing accurate non-linear deformation structural analysis for critical structures from a safety and weight perspective. For example, the nominal water landing for the Orion crew module (CM) is leading to the requirement for reliable predictions of vehicle structural response due to fluid-structure interactions. Nonlinear transient dynamics, using the commercial code LS-DYNA®, are used for these predictions. LS-DYNA® is capable of predicting CM/water interaction during impact as well as the flexible body behavior of the CM structure. Currently the code is used to predict crew member seat pallet displacements and accelerations for injury predictions and for predicting structural stress in critical components such as the heatshield. Accurate predictions are essential since landing loads are driving structural elements of the CM design. Since limited test data are available to validate the numerical simulations for this application, work is underway to correlate the simulations with data obtained from the NESC's full-scale CM water drop test to validate LS-DYNA® results to minimize vehicle weight.

"The flexibility and deep technical depth of the NESC has helped us to validate our project decisions and enhance our mission success."

Mr. James Free,
GRC Deputy
Center Director

Space Operations

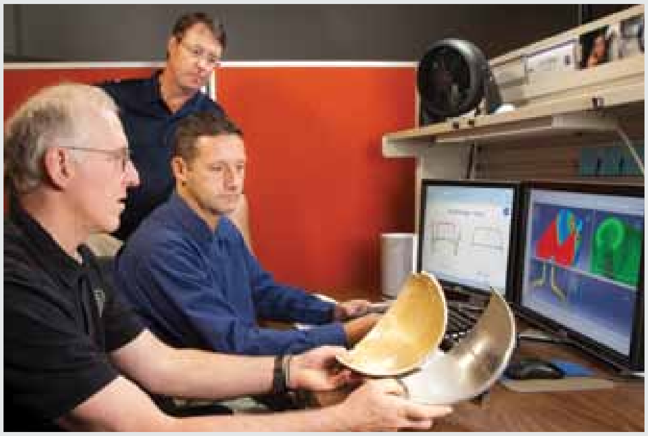
GRC support to the ISS Solar Alpha Rotary Joint (SARJ) anomaly included experimental work to mimic the SARJ on-orbit conditions after the STS-126 mission completed SARJ system servicing. The GRC vacuum roller rig (VRR) was used to replicate the conditions that created the wear debris found on-orbit. The worn rig rollers were then lubricated using the same grease as was provided on-orbit and testing continued in a time-accelerated manner to simulate the equivalent of 15 years of service. The testing demonstrated that so long as adequate lubrication is maintained, the structural integrity and operational effectiveness was sustainable for the simulated 15 years of service life. Testing using the VRR continues to study the lubricant life, mechanism health monitoring, and alternative roller materials for the SARJ system.

Science

GRC has aided the NESC in its support of Mars Science Laboratory's Surface Analysis at Mars vacuum pump development by conducting rotodynamic modeling of the pump's high-speed motor, bearing failure analyses, and finite element modeling of the bearing cages. The Center's expertise has helped guide the assembly and testing of this critical hardware and helped explain observed behavior during development testing.

Technical Discipline Teams

GRC supports several TDTs and working groups including the NESC Composite Pressure Vessel (COPV) Working Group. COPV Working Group members initiated the carbon fiber stress rupture test project with Lawrence Livermore National Laboratories. A phased project approach calls for testing of carbon fiber strands followed by pressure vessel stress rupture testing. Preliminary analysis for the design of the strand testing and the finite element analysis of the pressure vessel test article were completed to make critical design evaluations. Results of this project will support life prediction for vessels on the ISS and Constellation Programs. GRC also supported the NESC Systems Analysis Team that implemented NASA Standard for Modeling and Simulation (NASA-STD 7009).



From front, Dr. John Thesken, Eric Baker, and James Sutter, GRC members of the COPV Working Group, examine an imperfectly released liner-overwrap interface in the context of modeling approaches for finite element analyses of composite pressure vessels.

Adam Howard (left) and Chris Dellacorte reviewing the rotodynamics model of the 100,000 rpm Surface Analysis at Mars (SAM) vacuum pump to be flown on the MSL to study the make-up of Mars.

(From left) Denney Keys/NASA Technical Fellow for Electrical Power, Dr. George Dakermanji/MEI, Dr. Hari Vaidyanathan/COMSAT, and Leonine Lee/GSFC Lead Battery Engineer test a spare WMAP CPV NiH2 battery to help assess WMAP in-flight anomalies.

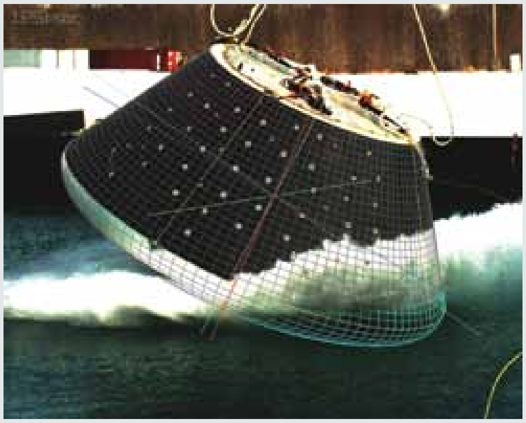
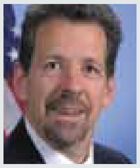


Image of the Orion crew module boilerplate overlaid with model mesh to approximate the submerged area.

The Goddard Space Flight Center (GSFC) along with its Wallops Flight Facility (WFF) continued participation in a wide range of NESC activities during 2010. More than 90 GSFC and WFF scientists, engineers, and technicians made significant contributions to NASA's Science Exploration, Exploration Systems, and Space Operations missions. The NASA Technical Fellows for Avionics, Electrical Power, Guidance Navigation and Control, Mechanical Systems and Software are resident at GSFC.

John H. Day
NESC's Chief Engineer at GSFC



Timothy Trenkle
NESC's Chief Engineer at GSFC

Exploration Systems

GSFC provided essential support to critical NESC assessments for the Constellation Program, including the Crew Exploration Vehicle (CEV) Parachute Assembly System (CPAS) Assessment, the Ares Control Sensitivity to Orion Slosh Dynamics Review, the Ares First Stage Avionics Thermal Study, as well as the Crew Module Water Landing Modeling Assessment (CMWLMA). The GSFC Wallops Flight Facility (WFF) led development and testing of the avionics and associate instrumentation for the Crew Module (CM) simulator, which exhibited exceptional performance during water drop tests.

Science

GSFC initiated and contributed to NESC activities for important Space and Earth Science missions, including assessment of Cryocooler Disturbance Models for the James Webb Space Telescope (JWST), the Taurus XL Fairing Frangible Separation Ring thermal assessment for the Glory mission, the Hayabusa Sample Return Reentry Observation Review, and the emergency Problem Resolution Team (PRT) on the anomalous in-flight performance of the common pressure vessel (CPV) nickel hydrogen (NiH2) battery aboard the Wilkinson Microwave Anisotropy Probe (WMAP). According to the flight operations team, WMAP (2009 most-cited space mission in science) would not have successfully completed 2010 science operations without the help and input of the NESC Team.

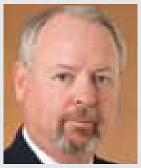
Space Operations

GSFC played a key role in NESC reviews and assessments that benefited critical Space Operations Programs, including review of the International Space Station (ISS) Alpha Magnetic Spectrometer payload, review of the ISS Communications Navigation & Networking Re-Configurable Testbed (CoNNeCT) antenna gimbal structural analysis, the Tracking & Data Relay Satellite System (TDRSS) Reaction Wheel Assembly (RWA) Lubricant Contamination assessment, as well as continued statistical analysis of the Shuttle External Tank Foam Loss for the NESC Engineering Statistics Team.

General

GSFC provided technical support or leadership to a variety of NESC discipline advancing activities, including the Fastener Workshop, Fault Management Handbook, Multi-Layer Ceramic Capacitor (MLCC) study, and Programmable Logic Devices study. GSFC has made extensive contributions to technical leadership of NESC support to the National Highway Traffic Safety Administration (NHTSA) investigation of automobile sudden acceleration. Component-level avionics testing at GSFC, along with NESC software and systems-level testing at automobile test facilities, are providing better understanding of functionality and vulnerabilities to sudden acceleration.

In 2010, the Jet Propulsion Laboratory (JPL) scientists and engineers supported numerous NESC assessments for the Science and Exploration Systems Mission Directorates, and the Robotics Operations Technical Discipline Team (TDT).



Lloyd Keith
NESC's Chief Engineer at JPL

Exploration Systems

JPL is leading the NESC Crew Module Water Landing and Modeling Assessment. These tests and analyses provide the necessary verification to correlate design results based on models and simulations to a full-scale test article dropped into water at nominal landing velocities and attitudes. The first set of drop tests has been completed and the planning and implementation of the second set of tests is underway. The accelerated schedule and independence of the drop tests and subsequent evaluation, provides for an early risk characterization for the next crewed vehicle potentially influencing 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 (COPV) failure mode) based on the needs identified in previous NESC assessments. Based on this plan, the NESC has proceeded with a stress rupture model development program for which JPL subject matter experts provide technical leadership. This effort will require testing of both strands and subscale COPVs to provide adequate data and analytical effort that will provide an approach that can be used across all NASA programs and projects.

General

JPL is supporting the sudden acceleration investigation for NHTSA by providing the NESC assessment team with software and systems engineering experts. The Wireless Avionics team developed preliminary prototypes to prove out the concepts for using wireless avionic systems in space. Ames Research Center, GSFC, JPL and JSC avionics engineers are cooperatively working this task.

Science

JPL actively supported a number of assessments including vibroacoustic environments, thermal performance database development, software tools, cryocooler vibration, battery usage in operational missions, and pyrovalve reliability. JPL provides leadership for the NESC CPVWG, which is responsible for understanding and communicating issues and risks associated with state-of-the-art and emerging composite pressure vessel technology. The CPVWG is tasked with the development of appropriate strategies, approaches, and methodologies to minimize technical risk associated with composite pressure vessels and to create/revise technical requirements to mitigate this risk for future human and robotic space missions. The CPVWG coordinates with programs and projects throughout NASA, and has been working proactively to address COPV mechanical modeling concerns, non-destructive testing, lifetime assessment issues and standards development. While COPVs have been a priority, the CPVWG is also reviewing the state-of-the-art of cryogenic propellant tanks to understand the technology limitations and path forward to developing the technology.

Robotics Operations TDT

The Robotics Operations TDT, led by JPL, is working several tasks to advance robotic exploration. The entry, descent, and landing (EDL) task developed a database that is capturing at-risk EDL data to benefit future spacecraft designs. EDL experts from Goddard Space Flight Center (GSFC), JPL, Johnson Space Center (JSC), and Langley Research Center are populating the database with at-risk EDL data and expanding the base of users. The amount of data available in the database is increasing rapidly in this phase of the task.

(Far Left) Water drop testing of an Orion crew module boilerplate.

(Right) COPV testing.

Dr. Nancy Currie
NESC's Chief Engineer at JSC

NESC personnel at Johnson Space Center (JSC) and the White Sands Test Facility (WSTF) support the safe and successful execution of the Space Shuttle Program (SSP), the continuous operation of the International Space Station (ISS), and the development of the human-tended spacecraft. NESC personnel at JSC provide real-time mission support as a member of both the SSP and ISS Mission Management teams and serves as a non-voting member on major technical boards for the SSP, ISS and the Constellation Program. In recognition of the importance of sharing lessons learned from decades of human spaceflight engineering and vehicle design, assistance was also provided to spacecraft developers through the Commercial Crew and Cargo Program. The NASA Technical Fellows for Life Support/Active Thermal, Loads and Dynamics, and Passive Thermal and the NESC Deputy Director for Safety are resident at JSC. Over 40 engineers from JSC support NESC assessments.

Exploration Systems

The NESC is actively engaged at all levels of the CxP. The Technical Fellows and other NESC personnel participated as an independent review team during technical sessions associated with the Program's Preliminary Design Review. Utilizing expertise from across NASA and other government agencies, industry and academia; NESC teams continued their involvement in activities associated with occupant protection during dynamic phases of flight of the Orion spacecraft. Numerical models were developed and refined and tests were conducted to predict biomechanical response and determine the risk of crew injury during landing scenarios. This data is being used to define human systems integration requirements for future spacecraft and to assess the level of occupant protection by future vehicle designs. Crew seat/pallet isolation design concepts designed to mitigate the potential deleterious effects of thrust oscillations during ascent and landing accelerations were developed and tested. The NESC developed a framework to determine when it is acceptable to fly a crewed mission on a launch vehicle/spacecraft for the first time. Independent assessments of critical issues affecting Constellation elements include: launch abort vehicle (LAV) stabilization during transonic abort, LAV jet interaction aerodynamics, Ares I control sensitivity to Orion service module tank slosh dynamics, design of the liquid oxygen damper, and reliability of the Crew Exploration Vehicle Parachute Assembly System. NESC personnel also supported an Agency-led study of developing an emergency return vehicle to support the ISS and served as members of CxP and Project Standing Review Boards.

Space Operations

NESC discipline experts supported the anomaly investigation of the ISS external active thermal control ammonia pump module failure and performed thermal analysis associated with removal and replacement of the failed unit and restart of the system. An independent assessment of the proposed STS-135 mission was conducted, including plans and procedures to use Soyuz spacecraft as an alternate means of crew return in the event the Space Shuttle is unable to return safely to Earth. NESC Life Support subject matter experts provided a detailed technical review of the risks associated with the ISS Sabatier carbon dioxide reduction system to determine its readiness for operation. The Technical Fellows for Life Support/Active Thermal and Passive Thermal provided oversight of analysis and test to investigate the cause and effects of face sheet damage on one of the ISS radiator panels. At the request of the ISS Program Manager, the NESC reviewed ISS micrometeoroid and orbital debris (MMOD) environment models, damage prediction and ballistic limit equations, and damage tolerance and failure criteria. The team also assessed the effects of proposed augmentations to ISS elements and began conceptual work for external shielding to provide enhanced protection from MMOD in high risk areas. The NESC provided technical support to an SSP review of a reaction control system thruster event during test stand operations and to ISS investigations of flex hose failures during proof pressure testing, composite overwrapped pressure vessel failure modes, and damage modes and potential on-orbit remediation options for the solar array rotary joint. During Space Shuttle missions, members of the Passive Thermal Technical Discipline Team provided real-time support to the Space Shuttle Thermal Protection System Damage Assessment Team.

Science

JSC NESC personnel performed detailed analysis and supported review activities associated with venting of the membrane sunshield on the James Webb Space Telescope. NESC thermal experts supported the Alpha Magnetic Spectrometer Project by assessing the thermal effects of replacing the planned superconducting magnet with a previously flown design.

WSTF Pyro Team doing test setups: From left, Technician Rick Madrid, WSTF Project Leader, Steve McDougle, Test Conductor Tony Carden and Assessment Lead, Regor Saulsberry.

NESC Statistician Ken Johnson (left) observes as Test Conductor Tony Carden (right) aligns the optical pyrometer for temperature measurements of the Y-PCA.

Ralph Lucero visually inspects a COPV as Chris Keddy and Dan Hartness (right) discuss computer modeling of COPVs.

White Sands Test Facility (WSTF) personnel are participating in several NESC activities including two pyrotechnic-operated valve (pyrovalve) assessments for the Propulsion Technical Discipline Team; in-depth planning and data collection for the NESC alternate launch abort system study and nondestructive evaluation (NDE) and modeling for the Composite Pressure Vessel Working Group (CPVWG).

Pyrovalve Booster Interface Temperature Measurement: Testing quantified improvements of a new stainless steel (SS) primer chamber assembly (PCA) with V-shaped flame channels (V-PCA) over more commonly used aluminum PCAs with Y-shaped channels (Y-PCA). The SS V-PCA was significantly improved overall, except dual simultaneous initiator firings where no improvement was noted and should be avoided.

Max Launch Abort System Objective System Concept Study: A Reaction Control System (RCS) engineer from JSC is leading a WSTF team to assist with the planning for manufacturing, assembling, and testing of an RCS for the design study. The team plans to evaluate subsystem performance during hot-fire tests; decontaminate, disassemble, and ship the RCS to an integration facility; and assist with subsystem installation, checkouts, and acceptance testing at the integration launch facility.

Pyrovalve Reliability Assessment for Expendable Launch Vehicle (ELV) Payloads: Because of their light weight and reliability, pyrovalves are used in propulsion systems to isolate hazardous propellants. However, there are questions about leakage and the number of isolation points the pyrovalves represent. A WSTF-led team is evaluating pyrovalve design and construction, historical leakage, inadvertent operation, and reliability to help the ELV payload community develop safety policies.

Composite Overwrapped Pressure Vessels: The CPVWG and the NASA NDE Working Group are producing a new laser profilometer to map the interiors of cylindrical composite pressure vessels up to 55-in. long. The first generation system has successfully mapped the displacements resulting from wrapping, pressure proof testing, and accelerated stress rupture testing. External profilometry and eddy current scanning capabilities are being added to this system. Continued analysis of acoustic emissions has improved failure prediction methods.

WSTF has also developed a specialized library of stress rupture and static strength data for various fiber types from the strand level up to the flight-weight component level. Data sets are available on the NESC CPVWG website. Unique data collected from carefully controlled carbon overwrapped vessel stress rupture testing is highly sought after by the aerospace and alternative fuel vehicle industry. This testing will generate additional data needed for current flight rational and for future design and modeling of more complex vessels.

The NESC is involved in multiple activities and projects at the Kennedy Space Center (KSC). Likewise, KSC continues to provide support and expertise to a wide variety of NESC assessments and testing across the Agency. More than 20 KSC scientists, engineers, and technicians of various disciplines were active in NESC assessments. KSC engineers provided expertise on numerous NESC Technical Discipline Teams (TDTs), including: Guidance, Navigation, and Control; Power; Avionics; Flight Mechanics; Loads and Dynamics; Systems Engineering; and Structures.

Stephen Minute
NESC's Chief Engineer at KSC

Exploration Systems

Max Launch Abort System (MLAS) Objective System Concept Study: With the success of the first MLAS flight test vehicle (FTV), the NESC is exploring improvements to the original MLAS design in the Objective System Concept study. An operations engineer with KSC's Vehicle Processing Directorate is working with the NESC on planning of this complex project.

Commercial Crew: NASA Technical Fellows are sharing their knowledge in developing the appropriate specifications and standards in support of the KSC-based Commercial Crew Program. In particular, the Technical Fellows are working with the various Program and Center engineering organizations in developing the appropriate standards for use in the Commercial Crew Human Rating Plan. Also, KSC is supporting the NESC in an independent assessment of the Orbital Sciences Corporation plans for testing their Taurus II rocket. In particular, KSC is assisting with a technical review of ground acoustics, plume impingement, and induced environments.

Space Operations

The NESC was engaged in several Program assessments that affected ground processing at KSC including: Space Shuttle main engine ignition overpressure and nozzle cracks, expendable launch vehicle pyrovalve reliability, Taurus frangible joint system and Space Shuttle orbiter flow control valve poppet cracking. In particular, the NESC is involved with the on-going STS-133 Shuttle External Tank (ET-137) hydrogen vent umbilical leakage and intertank stringer crack issues. During Shuttle propellant loading for launch of STS-133, ET-137 experienced excessive hydrogen leakage at the ET/ground interface. The NESC was involved in disassembly and replacement of the ground-half vent line disconnect and included a seal expert in discussions with KSC to improve understanding of seal and sealing surface interactions, as well as develop improved assembly techniques. During the same STS-133 propellant loading two ET intertank structural stringers developed cracks. The NESC is involved with the loads analysis, nondestructive evaluation techniques, metallurgical forensics, and the subsequent instrumentation scheme for follow-on testing.

General

NESC expertise is not only used with in NASA but crosses boundaries into other federal agencies too. NESC is consulting with the National Highway Transportation Safety Administration on the problem of unintended acceleration on passenger vehicles with electronic throttle controls. Two engineers from KSC Engineering are involved in the investigation.

NESC personnel and NESC resident engineers from KSC participate in the weekly NESC Review Board to peer review all technical products produced by NESC assessments.

The Alpha Magnetic Spectrometer (AMS-02) is being prepared in the ISS processing facility for launch on STS-134. The NESC evaluated the planned installation and operation of AMS-02 in response to a major reconfiguration of the instrument late in the pre-launch and integration phase.

Walter Engelund

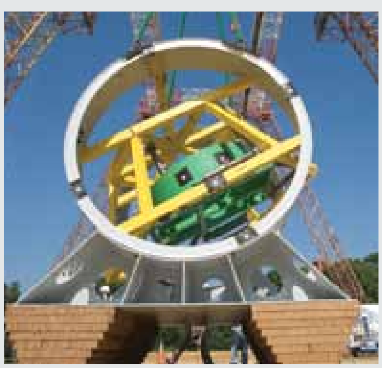
NESC's Chief Engineer at LaRC

Langley Research Center (LaRC) continues to support the NESC mission to address the Agency's high risk programs and projects. Over 240 scientists, engineers and contractors at LaRC 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. LaRC is the host Center for the NESC Directors Office, Principal Engineers Office, Systems Engineering Office, and the Management and Technical Support Office. LaRC is also home to the NASA Technical Fellows for Aerosciences, Flight Mechanics, Materials, Nondestructive Evaluation, and Structures.

Exploration Systems

Composite Crew Module – Damage Tolerance Testing: In September 2009, LaRC received the NESC Composite Crew Module (CCM) for full scale testing. The objective of the testing was to characterize pre-test analytical finite element model strain predictions against measured strain readings. The testing was done at the LaRC Combined Loads Test System (COLTS) facility. The test matrix included a damage tolerance assessment phase where damage was intentionally induced to the test article, characterized using ultrasonic, flash infrared, and radiographic inspection techniques, and then subjected to ultimate design loads and cyclic loads to assess whether detrimental damage growth occurred. LaRC expertise in acoustic emission was also provided during test to monitor for events of interest. The final CCM test was an internal hydrostatic test to failure.

Science



The NESC employed the LaRC's Landing and Impact Research (LandIR) facility to investigate energy attenuating seat struts for the Orion crew module.

Mars Science Laboratory (MSL) Reaction Control System (RCS) Aero Interaction Evaluation: LaRC provided technical leadership and expertise to the NESC investigation to help understand and characterize the complex aerodynamic flow phenomena produced when the MSL entry vehicle fires its RCS jets in the wake of a hypersonic flowfield during the Entry, Descent, and Landing (EDL) phase. Early RCS jet location designs on the MSL aeroshell were subject to potential flight control reversals, which may have proven catastrophic to the mission during EDL. The jets were redesigned and relocated to mitigate this potential issue. The NESC developed and executed a wind tunnel test in the LaRC 31-inch Mach 10 wind tunnel and also conducted a parallel computational fluid dynamics analysis campaign to validate the new design and ensure the modified RCS design works effectively. These capabilities and test techniques will also be useful on future entry vehicles with similar RCS design requirements, including the Constellation Program Orion Project and Commercial Crew Systems.

Cassini – Titan Flyby: LaRC personnel led the NESC assessment of the Cassini Titan "T-70" flyby to predict the range of atmospheric characteristics, aerodynamic torques, and heating likely to be encountered by the spacecraft. To measure Titan's magnetic field, the Cassini spacecraft must dip into the atmosphere below the ionoshpere and within 880 kilometers (547 miles) of the surface, 70 km lower than any previous flyby. If the atmosphere is too thick during this low approach, then large aerodynamic torques could drive the spacecraft out of control or high heating could damage sensitive instruments. The NESC team recommended a spacecraft orientation that would minimize the aerodynamic torques and maximize the controllability (safety) margin during the closest approach. The flyby was successfully completed on June 21, 2010, where the spacecraft pointing was maintained within the predicted limits.

From Left, Dr. Jeremy Pinier, David Witte and Dr. David Schuster in the LaRC Transonic Dynamics Tunnel, examine instrumentation on an alternative launch abort concept that employs grid fins for stability.

Model of the Mars Science Laboratory mounted in the LaRC 31-inch Mach 10 wind tunnel.

More than 100 scientists, engineers, and technicians from the Marshall Space Flight Center (MSFC) Engineering, Safety and Mission Assurance, and Space Shuttle Program communities provided crucial technical support to over 30 NESC assessments in 2010. These investigations involved the areas of exploration systems, space operations, science, and crosscutting discipline activities. The NASA Technical Fellow for Propulsion is resident at MSFC.

Steve Gentz
NESC's Chief Engineer at MSFC

Exploration Systems

Shell Buckling Knockdown Factor (SBKF): Continuation of SBKF investigations included fabrication and testing of 8- and 27.5-foot diameter isogrid cylinders. Critical support was provided by several MSFC laboratories, departments, and quality organizations. Data gathered from this testing is applicable to the Constellation Program, future heavy lift booster designs, and is useful to structural analysts in general to enhance understanding of design margin in metal and composite tanks and other shell structures. Instrumentation of the first 27.5-foot diameter test article continued through November with initial structural testing in December. Additional testing including instrumentation of the second 27.5-foot diameter test article is anticipated for 2011.

Space Operations

Space Shuttle Program (SSP): MSFC technical experts continued to participate in readiness reviews for each Space Shuttle flight, including those of the Space Shuttle propulsion elements, the Center Director's evaluation, and the SSP and Agency Certificate of Flight Readiness activities. Some of these resulted in involvement in specific focus areas including external tank foam loss investigation, and Orbiter main propulsion system gaseous hydrogen flow control valve, and reaction control system/orbital maneuvering system thruster evaluations.

Science

MSFC Engineering provided invaluable in-depth analysis and review of the James Webb Space Telescope (JWST) cryocooler coolant flow models. This effort was a proactive request from the JWST Program for an independent review to determine if a credible risk exists with the operation of the cryocooler system on the mid-infrared instrument detectors.

General

The NESC Propulsion Technical Discipline Team sponsored work within the Engineering community to enhance the Agency's propulsion capabilities in three key areas: knowledge transfer, propellant readiness level (PRL) determination, and near net shape fabrications of complex turbomachinery components. Propulsion training and knowledge dissemination were enhanced through the development of a hands-on propulsion learning center. The first version of the PRL (based on the technology readiness level categories) was released for review and presented at a July 2010 Joint Propulsion Conference. The PRL is an approach for determining the level of maturity in a propellant knowledge (i.e., how well is it characterized, what experience do we have applying it). Finally, powder metallurgy manufacturing was used to build a prototype turbopump impeller for cryogenic flow testing. Other discipline advancing and knowledge transfer work within MSFC Engineering supported by the NESC included updates to NASA specifications and standards, the Composite Pressure Vessel Working Group, and hosting the annual Agency Battery Workshop.

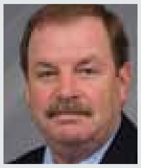
Combined shear/tension testing of aerospace fasteners by James Hodo, Electronics Technician in the Materials and Processing Lab.

The 27.5-foot-diameter Test Article 1 being installed into the MSFC 7-Axis Milling Machine Facility for the SBKF Project.

Lester Langford of Jacobs Technology, Inc. makes measurement preparations for sub-scale acoustic testing of the A-3 Test Stand.

Richard Franzl (left) and Mark Turowski of Jacobs Technology perform integrated monitoring of chemical steam generator tests for the A-3 Test Stand.

This year, over 20 Stennis Space Center (SSC) scientists and engineers supported several NESC-sponsored activities focused on A-3 Test Stand support and Health Monitoring system improvements. Activities employed the unique capabilities and facilities available at SSC.



Michael Smiles
NESC's Chief Engineer at SSC

Exploration Systems

A-3 Test Stand: SSC is constructing the A-3 Test Stand to enable liquid-fueled rocket engine testing in simulated altitude conditions. The NESC has been engaged in several activities supporting its design. The A-3 Chief Engineer requested that the NESC perform a structural dynamics analysis of the test stand and its major components, which will be subjected to significant vibroacoustic environments during test operations. The NESC has assembled a team of experts to provide analytical confirmation that the dynamic environment will not have a detrimental effect on the stand structure and components such as propellant run tanks, test cell, diffuser, test article, piping systems, and measurement/monitor/control systems.

Sub-scale testing revealed an issue of high concentrations of oxygen produced by chemical steam generators, used to create a vacuum in the test cell, reacting with un-burned hydrogen produced by the engine causing an "un-start "condition within the diffuser. The NESC provided technical expertise in an independent review of the A-3 test stand.

A series of sub-scale tests were conducted to understand the effects of water-injection acoustic mitigation techniques on reducing the diffuser exhaust noise. Variables investigated included high velocity water injected in the diffuser exhaust plume at different axial locations, impingement angles, and flow rates. NESC sponsored acoustic measurements and analysis led to improvements in the diffuser noise abatement.

Integrated Systems Health Management (ISHM): A pilot application was developed to investigate the application and utility of ISHM in a rocket propulsion test environment. The chemical steam generator (CSG) test program at SSC was selected for this project. The prototype completed a comprehensive ISHM model for the CSG program test article that included data, knowledge, sensor validation information, anomaly detection, and diagnosis. The ISHM application to the propulsion test environment at SSC demonstrated significant improvements in both data analysis scope and critical test data/information access.

General

A group of SSC junior engineers and contractor engineers were sponsored by the NESC in support of the Max Launch Abort System test vehicle and the rapid prototype development of a Smart and Intelligent Sensor Payload Project sponsored by the Center. These individuals presented to SSC management on their involvement and resulting professional growth.

"The NESC has been a valuable resource to the A-3 Test Stand 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."

— Jody Woods, A-3 Test Stand Chief Engineer, Stennis Space Center

NESC Honor Awards

Left to right: Eric Schleicher (Sierra Nevada Corporation), Wade Jackson (LaRC); William Schonberg (Missouri University of Science and Technology); Charles Lawrence (GRC); Marshall Neipert (JSC); Mark Schoenenberger (LaRC); Jane Malin (JSC); Kenneth Wright (University of Alabama – Huntsville); Tim Wilson (NESC Deputy Director/presenter); Sotiris Kellas (LaRC); Elizabeth Opila (University of Virginia); Patrick Johnston (LaRC); Ralph Roe, Jr. (NESC Director/presenter); Christopher Dellacorte (GRC); Joel Williamsen (Institute for Defense Analyses); Frederick Brust (Engineering Mechanics of Columbus Corporation); Paul Tartabini (LaRC); John Hengel (MSFC); Timothy Krantz (GRC); Patrick Forrester (NESC Chief Astronaut/presenter); Alan Leveille (independent consultant).

NESC Director's Award

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

Mark Schoenenberger

In recognition of advocacy, development, leadership and execution of the NASA Engineering and Safety Center's Mars Science Laboratory Aerodynamic/Reaction Control System interaction validation effort

NESC Leadership Award

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

Sotiris Kellas

In recognition of outstanding leadership in managing the test phase of the Composite Crew Module Project

William P. Schonberg

In recognition of outstanding leadership, technical insight and support of micrometeoroid and orbital debris (MMOD) protection and damage prediction for the NASA Engineering and Safety Center MMOD assessments

Joel Williamsen

In recognition of outstanding leadership and technical insight into the NASA Engineering and Safety Center micrometeoroid and orbital debris assessment activities

NESC Engineering Excellence Award

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

Frederick W. Brust

In recognition of contributions to the NESC Critical Initial Flaw Size Team's engineering and analysis on weld sequences for the Upper Stage Simulator of the Ares 1-X vehicle

Christopher Dellacorte

In recognition of exceptional technical support in the area of tribology and mechanical systems as exemplified in the International Space Station Solar Array Alpha Rotary Joint recovery

Wade C. Jackson

In recognition of engineering excellence in developing and implementing the impact delivery system for characterizing durability and damage tolerance of composites on the Composite Crew Module Project

Patrick H. Johnston

In recognition of engineering excellence in developing a non-destructive phased array ultrasonic inspection technique for use on Pi-preforms on the Composite Crew Module Project

Timothy L. Krantz

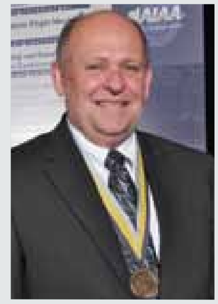
In recognition of engineering excellence in the resolution of the International Space Station Solar Array Alpha Rotary Joint anomaly including critical testing and data reduction that contributed to the development of the most probable root cause

Charles Lawrence

In recognition of exceptional technical support to the Orion occupant protection study leading to advancements in biomechanical injury prediction and improvements in spacecraft seat and restraint designs

KSC Engineers receive NESC Group Achievement Awards for their work on MLAS and the NESC Resident Engineering program. Pictured from left to right are: Pat Simpkins, Director of Engineering at KSC; Sarah Quach, MLAS Resident Engineer; Samantha Manning, MLAS Resident Engineer; and Steve Minute, NESC Chief Engineer at KSC.

Dr. Michael Gilbert named AIAA engineer of the year



Engineer of the Year Award issued by the American Institute of Aeronautics and Astronautics (AIAA) was awarded to Dr. Michael Gilbert for his work as the Chief Engineer on the successful test flight of the Max Launch Abort System in July, 2009. The AIAA Engineer of the Year Award is presented to a member of AIAA who has made a recent individual contribution in the application of scientific and mathematical principles leading to a significant accomplishment or event worthy of AIAA's national or international recognition.

Alan R. Leveille

In recognition of engineering excellence in determining the cause and corrective action of the International Space Station Urine Processing Assembly-Distillation Assembly bearing failures

Jane T. Malin

In recognition of engineering excellence and exceptional leadership within the Data Mining and Trending Working Group and during development of a linguistically based data mining tool

Marshall Neipert

In recognition of engineering excellence in the LS-DYNA analysis performed in support of the International Space Station Radiator Anomaly Assessment which led to an understanding of the potential failure mode root cause

Elizabeth J. Opila

In recognition of engineering excellence as a member of the NASA Engineering and Safety Center supported Reinforced Carbon Carbon Root Cause Investigation Team

Eric Schleicher

In recognition of engineering excellence in developing analytical models, developing and managing pre-test strain predictions, and correlating post-test strain results for the Composite Crew Module Project

Paul V. Tartabini

In recognition of engineering excellence in the development and evaluation of Max Launch Abort System Objective System designs

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

Crew Exploration Vehicle Parachute Assembly System Independent Reliability Assessment Team

In recognition of outstanding contributions to the Orion Crew Exploration Vehicle parachute assembly system design with a focus on reliability and development test plan improvements

Composite Crew Module Non-Destructive Evaluation and Test Team

In recognition of outstanding contributions in the field of Non-Destructive Evaluation and test execution on the Composite Crew Module Project (award accepted by Sotiris Kellas on behalf of the team)

International Space Station Plasma Contactor Utilization Assessment Team

In recognition of outstanding support to the investigation of plasma environmental effects on the International Space Station (award accepted by Kenneth Wright on behalf of the team)

NESC Orion Landing Attenuation and Ares-1 Thrust Oscillation Isolation Team

In recognition of outstanding effort in the development of alternative designs for the Orion landing attenuation system and for engineering an Ares-1 thrust oscillation load mitigation system through crew pallet isolation (award accepted by Charles Lawrence on behalf of the team)

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 27 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 NESC's Deputy Director. 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 29 years of engineering and management experience supporting the Space Shuttle Program.

Michael P. Blythe
NESC Deputy Director for Safety

Mr. Michael P. Blythe is 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 HQ. 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

Dr. Daniel Winterhalter
Chief Scientist

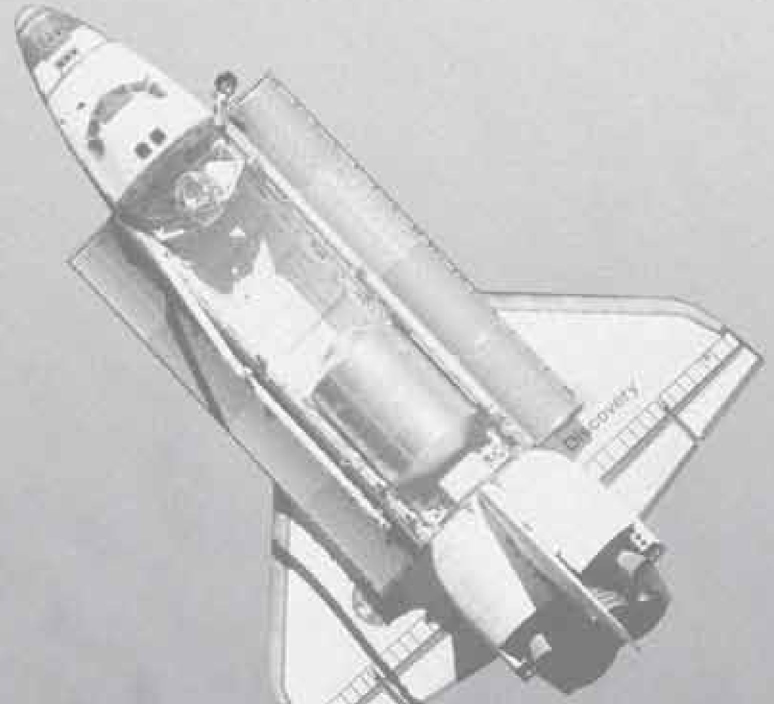
Dr. Daniel Winterhalter is NESC's Chief Scientist and is resident at the Jet Propulsion Laboratory (JPL). Dr. Winterhalter has over 32 years of experience as a research scientist at JPL. His research interests include the spatial evolution of the solar wind into the outer reaches of the heliosphere, 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.

Dawn M. Schaible
Manager, Systems Engineering Office

Ms. Dawn M. Schaible is Manager of 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 23 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 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 21 years of professional financial, accounting, and systems experience at NASA.



NESC Principal Engineers

Clinton H. Cragg

NESC Principal Engineer

Mr. Clinton H. Cragg is a Principal Engineer with NESC at Langley Research Center (LaRC). Mr. Cragg came to 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 32 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 NESC at Langley Research Center (LaRC). Dr. Gilbert was formerly the NESC Chief Engineer at LaRC. Before joining NESC, he was Head of the LaRC Systems Management Office. Dr. Gilbert has over 32 years of engineering, research, and management experience with aircraft, missile, spacecraft, Space Shuttle, and International Space Station programs.

Michael T. Kirsch

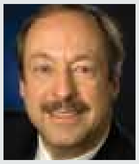
NESC Principal Engineer

Mr. Michael T. Kirsch is a Principal Engineer with NESC at Langley Research Center (LaRC). Mr. Kirsch joined 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 21 years of experience in managing projects and test facilities.

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 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 35 years of experience in System Safety, Propulsion and Explosive Safety, Mishap Investigation, Range Safety, Pressure Systems, Crane Safety and Orbital Debris Mitigation.

NESC Chief Engineers

Dr. Nancy J. Currie

NESC Chief Engineer

Dr. Nancy J. Currie is 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 22 years of expertise 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.

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 28 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.

Walter C. Engelund

NESC Chief Engineer

Mr. Walter C. Engelund is 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 21 years of experience as a recognized expert in launch and entry vehicle aerodynamics, atmospheric flight dynamics and hypersonic flight systems.

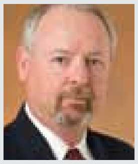
Steven J. Gentz

NESC Chief Engineer

Mr. Steven J. Gentz is 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 27 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 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 33 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.

NESC Chief Engineers *Continued*

Nans Kunz

NESC Chief Engineer

Mr. Nans Kunz is 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 32 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.

Richard T. Manella

NESC Chief Engineer

Mr. Richard T. Manella is NESC's Chief Engineer at Glenn Research Center (GRC). Mr. Manella joined the NESC from GRC, where he served as the first Chief of the Chief Engineers Office, an office which he established. Mr. Manella has over 23 years of engineering and management experience in structural dynamics and spaceflight systems.

Stephen A. Minute

NESC Chief Engineer

Mr. Stephen A. Minute is 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 26 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 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 25 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 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 44 years of management and technical experience leading missile and aircraft programs.

Timothy G. Trenkle

NESC Chief Engineer

Mr. Timothy G. Trenkle is NESC's Chief Engineer at Goddard Space Flight Center (GSFC). Mr. Trenkle joined the NESC from GSFC, where he has over 18 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). Mr. Trenkle is currently working a detailed assignment in the Joint Polar Satellite System (JPSS) Office at GSFC.

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 34 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 30 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 19 years of experience in performing aerodynamic, hydrodynamic, and engine system design and analysis of rocket propulsion.

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 32 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.

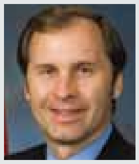
Denney J. Keys

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 30 years of private industry and NASA experience with electrical power systems.

NASA Technical Fellows *Continued*

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 30 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 29 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 24 years of experience lecturing on Human Factors, and another 18 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 22 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 26 years of experience in the commercial nuclear power industry and over 17 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 23 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 35 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 25 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 43 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 32 years of experience in the aerospace industry with expertise in aeroelasticity and integrated aerodynamic analysis.

The NESC Alumni

Frank H. Bauer
NESC Discipline Expert for Guidance Navigation and Control (2003 – 2004) Currently serving as the Exploration Systems Mission Directorate Chief Engineer at NASA HQ

J. Larry Crawford
NESC Deputy Director for Safety (2003 – 2004) 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 – 2009) 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 – 2008) 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 – 2007) 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 – 2009) 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 – 2008) 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 – 2008) Left the NESC to become Manager, Office of Safety and Mission Assurance at SSC

Patricia L. Dunnington
Manager, Management and Technical Support Office (2006 – 2008) Retired

Dr. Michael S. Freeman
NESC Chief Engineer at Ames Research Center (2003 – 2004) Retired

T. Randy Galloway
NESC Chief Engineer at Stennis Space Center (SSC) (2003 – 2004) Currently the Director of the Engineering and Test Directorate at SSC

Dr. Edward R. Generazio
NESC Discipline Expert for Nondestructive Evaluation (2003 – 2005) Left the NESC to become a Senior Research Engineer, Research Directorate, Langley Research Center

Dr. Richard J. Gilbrech
NESC Deputy Director (2003 – 2005) Currently the Associate Director at Stennis Space Center

Michael Hagopian
NESC Chief Engineer at Goddard Space Flight Center (GSFC) (2003 – 2007) 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 – 2007) Retired

Dr. Charles E. Harris
NESC Principal Engineer (2003 – 2006) Currently the Director, Research Directorate, Langley Research Center

Dr. Steven A. Hawley
NESC Chief Astronaut (2003 – 2004) 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 – 2006) 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 – 2007) Retired

Keith L. Hudkins
NASA Headquarters Office of the Chief Engineer Representative (2003 – 2007) Retired

Danny D. Johnston
NESC Chief Engineer at Marshall Space Flight Center (MSFC) (2003 – 2004) 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 – 2005) 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 – 2007) Retired

Dr. Dean A. Kontinos
NESC Chief Engineer at Ames Research Center (ARC) (2006 – 2007) 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 – 2006) Currently the Chief Engineer, Crew Exploration Vehicle Office at Johnson Space Center

Steven G. Labbe
NESC Discipline Expert for Flight Sciences (2003 – 2006) Currently the Chief Engineer, Constellation Program Office at Johnson Space Center

Matthew R. Landano
NESC Chief Engineer at NASA's Jet Propulsion Laboratory (JPL) (2003 – 2004) Returned to his assignment at JPL as the Director of Office of Safety and Mission Success

David S. Leckrone
NESC Chief Scientist (2003 – 2006) Left the NESC to become the Senior Project Scientist for the Hubble Space Telescope at Goddard Space Flight Center

John P. McManamen
NASA Technical Fellow for Mechanical Systems (2003 – 2007) Currently the Chief Engineer, Shuttle Program Office at Johnson Space Center

Brian K. Muirhead
NESC Chief Engineer at NASA's Jet Propulsion Laboratory (JPL) (2005 – 2007) Returned to his assignment as the Chief Engineer, Jet Propulsion Laboratory

Dr. Paul M. Munafo
NESC Deputy Director (2003 – 2004) 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 NESC's Management and Technical Support Office (2003 – 2004) 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 – 2009) Returned to her assignment as the Ames Research Center Chief Engineer

Dr. Shamim A. Rahman
NESC Chief Engineer at Stennis Space Center (SSC) (2005 – 2006) Left the NESC to become the Deputy Director of the Engineering and Test Directorate at SSC

Jerry L. Ross
NESC Chief Astronaut (2004 – 2006) 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 – 2010) Retired

Steven S. Scott
NESC Chief Engineer at Goddard Space Flight Center (2008 – 2009) NESC Discipline Expert (now called NASA Technical Fellow) for Software (2003 – 2005) Returned to his assignment as the Goddard Space Flight Center Chief Engineer

Bryan K. Smith
NESC Chief Engineer at Glenn Research Center (2008 – 2010) 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 – 2004) 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 – 2009) Returned to his assignment as the Langley Research Center Chief Engineer

NESC/NASA Technical Memoranda Published

	Publication Title	TM NUMBER
1.	Constellation Program (CxP) Crew Exploration Vehicle (CEV) Project Integrated Landing System	TM-2009-216165
2.	Evaluation of Computational Nondestructive Evaluation (NDE) Methodologies for Constellation Program (CxP) Fracture-Critical Structural Design	TM-2009-216167/Volume I
3.	Evaluation of Computational Nondestructive Evaluation (NDE) Methodologies for Constellation Program (CxP) Fracture-Critical Structural Design Appendices	TM-2009-216167/Volume II
4.	International Space Station Program (ISSP) Recurring Anomalies	TM-2009-216179/Volume I
5.	International Space Station Program (ISSP) Recurring Anomalies Volume II Part 1 Appendices A-I	TM-2009-216179/Volume II/Part 1
6.	International Space Station Program (ISSP) Recurring Anomalies Volume II Part 2 Appendix J	TM-2009-216179/Volume II/Part 2
7.	Flight Force Measurements (FFMs) of the Gamma-Ray Large Area Space Telescope (GLAST) / Delta II Flight	TM-2010-216180
8.	Assessment of International Space Station (ISS) Plasma Contactor Unit (PCU) Utilization	TM-2010-216683
9.	Extravehicular Mobility Unit (EMU) Phase VI Glove Thermal Micrometeoroid Garment (TMG) Damage 1 Mode Investigation	TM-2010-216686/Volume I
10.	Extravehicular Mobility Unit (EMU) Phase VI Glove Thermal Micrometeoroid Garment (TMG) Damage 1 Mode Investigation Appendix A	TM-2010-216686/Volume II/Part 1
11.	Extravehicular Mobility Unit (EMU) Phase VI Glove Thermal Micrometeoroid Garment (TMG) Damage 1 Mode Investigation Appendix B	TM-2010-216686/Volume II/Part 2
12.	International Space Station (ISS) Nitrogen/Oxygen Recharge System (NORS) Composite Overwrapped Pressure Vessel (COPV) Concept	TM-2010-216687
13.	Development, Design, Test, and Evaluation (DDT&E) Process for Robustness of Space Flight Programmable Logic Devices (PLDs)	TM-2010-216688
14.	Structures Peer Review for Constellation Program (CxP) Ares I-X Upper Stage Simulator (USS) Secondary Structures	TM-2010-216689
15.	Distributed Impact Detector System (DIDS) Health Monitoring System Evaluation	TM-2010-216694
16.	Problem Reporting Taxonomy and Data Preparation Tool Evaluation	TM-2010-216704
17.	RTAX-S Field Programmable Gate Array (FPGA) Risk Reduction	TM-2010-216705
18.	Orbiter Boundary Layer Transition Testing for Development of Aeroheating Prediction Methodology – Phase A	TM-2010-216707
19.	System Architectural Considerations on Reliable Guidance, Navigation, and Control (GN&C) for Constellation Program (CxP) Spacecraft	TM-2010-216716
20.	Constellation Program (CxP) Orion Project 26-AA Wind Tunnel Model Independent Failure Review	TM-2010-216717
21.	Assess Qualification of the Taurus Fairing Frangible Joint System	TM-2010-216718
22.	NASA Aerospace Flight Battery Program Generic Safety, Handling and Qualification Guidelines for Lithium-Ion (Li-Ion) Batteries; Availability of Source Materials for Lithium-Ion (Li-Ion) Batteries; Maintaining Technical Communications Related to Aerospace Batteries (NASA Aerospace Battery Workshop)	TM-2010-216727/Volume I
23.	NASA Aerospace Flight Battery Program Generic Safety, Handling and Qualification Guidelines for Lithium-Ion (Li-Ion) Batteries; Availability of Source Materials for Lithium-Ion (Li-Ion) Batteries; Maintaining Technical Communications Related to Aerospace Batteries (NASA Aerospace Battery Workshop)	TM-2010-216727/Volume II
24.	NASA Aerospace Flight Battery Program Recommendations for Technical Requirements for Inclusion in Aerospace Battery Procurements	TM-2010-216728/Volume I
25.	NASA Aerospace Flight Battery Program Recommendations for Technical Requirements for Inclusion in Aerospace Battery Procurements	TM-2010-216728/Volume II
26.	NASA Aerospace Flight Battery Program Wet Life of Nickel-Hydrogen (Ni-H2) Batteries	TM-2010-216729/Volume I
27.	NASA Aerospace Flight Battery Program Wet Life of Nickel-Hydrogen (Ni-H2) Batteries	TM-2010-216729/Volume II
28.	SpaceFibre High-Speed Serial Gigabit Data Link Technology Demonstration	TM-2010-216730
29.	Wilkinson Microwave Anisotropy Probe (WMAP) Battery Operations Problem Resolution Team (PRT)	TM-2010-216840
30.	Fracture Mechanics Based Methods Development for Composite Overwrapped Pressure Vessels (COPV) with Metallic Liners	TM-2010-216851
31.	Multilayer Ceramic Capacitors (MLCC) –Low Voltage Failure (LVF) Phenomenon	TM-2010-216852
32.	Constellation Program (CxP) Crew Exploration Vehicle (CEV) Parachute Assembly System (CPAS) Independent Design Reliability Assessment	TM-2010-216868/Volume I
33.	Constellation Program (CxP) Crew Exploration Vehicle (CEV) Parachute Assembly System (CPAS) Independent Design Reliability Assessment Appendices	TM-2010-216868/Volume II
34.	Independent Peer Review of Communications, Navigation, and Networking re-Configurable Testbed (CoNNeCT) Project Antenna Pointing Subsystem (APS) Integrated Gimbal Assembly (IGA) Structural Analysis	TM-2010-216870
35.	Simulation Framework for Rapid Entry, Descent, and Landing (EDL) Analysis	TM-2010-216867/Volume I
36.	Simulation Framework for Rapid Entry, Descent, and Landing (EDL) Analysis	TM-2010-216867/Volume II

Presented Papers

1. The NASA MLAS Flight Demonstration – A Review of a Highly Successful Test; AIAA SPACE 2010 Conference & Exposition; 08/31/2010 – 09/02/2010; Anaheim, CA
2. Composite Crew Module Primary Structure: A Case Study On Collaborative A Effort for the Design, Manufacture, and Test of a Full Scale Composite Crew Module Test Article; AIAA SPACE 2010 Conference & Exposition; 08/31/2010 – 09/02/2010; Anaheim, CA
3. The NASA MLAS Flight Demonstration – A Review of a Highly Successful Test; International Planetary Probe Workshop 2010 (IPPW-7); 06/14/2010 – 06/18/2010; Barcelona, Spain
4. Recent On-Orbit Anomalies Affecting EOS Terra and Wilkinson-Microwave Anisotropy Probe (W-MAP) Missions; Aerospace Space Power Workshop; 04/19/2010 – 04/22/2010; Manhattan Beach, CA
5. A Review of the NASA MLAS Flight Demonstration; 21st AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar; 05/23/2011 – 05/26/2011; Dublin, Ireland

Journal Articles Published

Entry, Descent, and Landing Architecture and Technology Challenges for Human Exploration Mars Missions; Journal of Cosmology

Space Shuttle Atlantis (OV-104) on mission STS-132 lifted off from launch pad 39A on May 14, 2010. Atlantis brought the Russian-built Mini Research Module-1 to the ISS. This was the 132nd overall Shuttle mission and the 34th mission dedicated to ISS assembly and maintenance.

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