FALL 2017

JANNAF NEWS

JOINT ARMY-NAVY-NASA-AIR FORCE
INTERAGENCY PROPULSION COMMITTEE

Volume 6, Issue 2 Revised Released November 6, 2017

Newport News to Host Fall 2017 JANNAF Meeting

JANNAF returns to Newport News, Va., for the December 2017 JANNAF Meeting. The meeting will be held at the Newport News Marriott at City Center, December 4-8, and will feature a joint meeting of the 48th Combustion (CS), 36th Airbreathing Propulsion (APS), 36th Exhaust Plume and Signatures (EPSS), and 30th Propulsion System Hazards (PSHS) Technical Subcommittees, along with the Programmatic Industrial Base (PIB) meeting. Classified sessions will be held at NASA Langley Research Center in nearby Hampton, Va. This year's meeting will be chaired by Mr. Kevin P. Ford, with the Naval Air Warfare Center Weapons Division, China Lake, Calif.

Mr. Thomas L. Boggs, a Scientist with Naval Systems, Incorporated in China Lake, Calif., with over 50 years of experience in the propulsion field, will serve as the keynote speaker on Tuesday, December 5. His presentation, "Fifty-Four Years at China Lake—Lessons Learned," will address some important lessons that he has learned during his career, which has included international, national (JANNAF in particular), Navy, and China Lake activities. His recent work

(continued on page 3)

Mr. Kevin P. Ford, Naval Air Warfare Center Weapons Division, China Lake, Calif., will chair the JANNAF meeting in Newport News, Va.

Editor: Benjamin Schwantes
410-992-7300, ext. 227
bschwantes@erg.jhu.edu

ERG Director: Peter E. Zeender
The Johns Hopkins University WSE ERG
10630 Little Patuxent Parkway, Suite 202
Columbia, Maryland 21044-3286
https://www.erg.jhu.edu
Fax: 410-730-4969

The JHU WSE Energetics Research Group (ERG) is the technical support contractor of the Joint Army-Navy-NASA-Air Force (JANNAF) Interagency Propulsion Committee. The purpose of JANNAF is to solve propulsion problems, affect coordination of technical programs, and promote an exchange of technical information in the areas of missile, space, and gun propulsion technology.

JANNAF News is available free of charge to the propulsion community. Reproduction of *JANNAF News* articles is permissible, with attribution. Neither the U.S. Government, ERG, nor any person acting on their behalf, assumes any liability resulting from the use or publication of the information contained in this document, or warrants that such use or publication of the information contained in this document will be free from privately owned rights.

The content of *JANNAF News* is approved for public release; distribution is unlimited.

ERG is the technical support contractor for the JANNAF Interagency Propulsion Committee operated by The Johns Hopkins University Whiting School of Engineering under contract NNM15AA02C.

Recent ERG Publications

PANEL DOCUMENTS

- Document Number: JANNAF-GL-2017-0001
  Abstract Number: 2017-0004
  Guidelines for the Structural Assessment of Solid Propellant Defects (JANNAF SMBS)
  May 2017
- Document Number: JANNAF-WS-2017-0005
  Abstract Number: 2017-0005
  Investigation of Gap Test Modeling and Instrumentation
  Feb 2017
- Document Number: JANNAF-PL-2017-0004
  Abstract Number: 2017-0006
  On the Relationship between Mechanical and Reactive Behavior in Engine Materials—JANNAF PSHS Shock/Impact Induced Reactions Panel Report
  Mar 2017
- Document Number: JANNAF-GL-2016-0001
  Abstract Number: 2016-0002
  Simulation Credibility in Continuum Physics: Advances in Verification, Uncertainty Propagation and Qualification, and Validation
  Oct 2016
- Document Number: JANNAF-WS-2016-0010
  Abstract Number: 2016-0007
  Collaborative Technical Interchange Meeting: Solid Rocket Motor Segmenting Best Practices and Lessons Learned
  Mar 2016

PROCEEDINGS

- Abstract Number: 2017-0002
  Meeting Proceedings from the "Pathways Beyond Low Earth Orbit / In-Space Chemical Propulsion Technical Interchange Meeting"
  Apr 2017
- Abstract Number: 2016-0005
  Classified Papers from the 35th APS / 35th EPSS Joint Subcommittee Meeting (U)
  May 2016
- Abstract Number: 2016-0003
  Additive Manufacturing for Propulsion Applications—JANNAF LPS-AMP Technical Interchange Meeting (TIM)
  Aug 2016
- Abstract Number: 2017-0003
  Meeting Proceedings from the "64th JPM / PIB / 44th SMBS / 40th PEDCS / 31st RNTS / 29th SEPS" (Kansas City, MO)
  May 2017

ERG Subscriptions

ERG forwarded GFY 2017 subscription renewal packets to its customer base for continued products and services. We would like to take this opportunity to inform the community that a minimum subscription of $1,775 entitles subscribers to one complimentary suite of JANNAF databases; one complimentary *JANNAF Journal*; and six hours (prepaid) of technical/bibliographic inquiry hours. For information concerning an ERG subscription and/or products and services, please contact Tricia Reider at 410-992-7300, ext. 222, or email treider@erg.jhu.edu. You may also visit https://www.erg.jhu.edu/subscriptions.

JANNAF Meeting, Newport News, Virginia... *continued from page 1*

on hazards associated with solid propellants and explosives will also be discussed.

During the 54 years that Boggs has worked as a scientist in the propulsion field, he has authored over 300 publications, edited several books, received three patents, and obtained seven secrecy order disclosures. An advocate for the "Science Based, Data Driven" research approach, Boggs has traveled across the country and around the world during his lengthy career in the field of propulsion and energetics.

Mr. Thomas L. Boggs is a past chairman of the JANNAF Propulsion Systems Hazards Subcommittee and the AIAA Propellants and Combustion Technical Committee. Following the massive explosions at the PEPCON plant in Henderson, Nevada, in 1988, he served as Chairman of the Tri-Service/NASA/Industry Committee on Response of Ammonium Perchlorate to Thermal and Mechanical Stimuli. Additionally, Thom has served as the Chairman of the Australia/Canada/U.K./U.S. Hazards of Energetic Materials and their Relation to Munitions Survivability organization and was the winner of the Achievement Award. Boggs has also organized several JANNAF workshops.

Boggs has repeatedly been acknowledged for his work and his volunteer service in the propulsion field. He received the annual Arthur S. Flemming Award, which recognizes the top 10 young men and women in Federal Service. Other awards for which he was a recipient include the Department of the Navy Meritorious Civilian Service Award, the Secretary of the Navy Career Service Award, the AIAA Wyld Propulsion Award, which is presented for outstanding achievement in the development or application of rocket propulsion systems, and the JANNAF Executive Committee Lifetime Achievement Award.

The four technical subcommittees meeting in Newport News have organized numerous sessions and workshops that will be of interest to the JANNAF community. CS will be hosting a Monday session on "Monopropellant and Hypergolic Combustion," which will emphasize advancements in ionic liquids, from molecular simulations at the component level

Mr. Thomas L. Boggs, Scientist, Naval Systems, Incorporated, will be the keynote speaker at the JANNAF Meeting in Newport News, Va.

to development and testing of thruster systems. The subcommittee has also planned an all-day specialist session for Wednesday on "Kinetics and Related Aspects of Combustion Chemistry." The session will be relevant to those actively involved in work related to chemical reaction phenomenon in the areas of modeling, diagnostics, and chemical kinetics as they apply to energetic materials over a range of lifecycle conditions, and featuring the development of new diagnostics, improved computational capabilities, and solid-state decomposition chemistry. CS will also host a session on "Diagnostics and Simulations" on Thursday, featuring presentations characterizing novel measurement systems performance and predicting properties of propellants.

APS will hold a total of 16 sessions running the gamut from small turbopropulsion technology to hypersonic technology applications. Highlights include

(continued on page 4)

JANNAF Meeting, Newport News, Virginia... *continued from page 3*

an overview specialist session on Monday, featuring updates from current hypersonics programs; a Monday evening specialist session on transitioning hypersonic systems from a science and technology mindset to one of test and evaluation; a Thursday session on hypersonic materials development, testing, design, and analysis; and a Thursday session on "High Speed Strike Weapon Technology Maturation."

In addition to the 34 papers being presented in 5 sessions, EPSS has developed 8 tutorials to document the process of performing flowfield and signature predictions. These physics-based tutorials include: overall considerations, rocket engine/motor considerations, continuum nozzle and plumes, rarefied flow, radiative transfer, environment effects, and electro-optical/infrared hardbody and plume signatures. Tutorials are being offered throughout the week; the intended audience is personnel new to the interdisciplinary field of flowfield and signature prediction, managers of such work, and established practitioners. The tutorials themselves will be recorded and made available through JANNAF to serve as a tool for future practitioners. Two EPSS workshops will also be held; the Monday evening "Launch Vehicle, Missile and Spacecraft Plume-Induced Environments" workshop will address plume flowfield, plume-induced thermal and aerodynamic effects, and signature topics of interest to both NASA and the DoD. The goal of this workshop is to foster collaboration between experts and identify areas of common technology, methods, and applications within the community. On Wednesday, EPSS will host the "Plume/Flowfield/Hardbody Signature Prediction Capability as a National Asset" workshop to highlight the broad spectrum of user communities in the nation that have a vested interest in the continued existence and advancement of plume/wake/hypersonic flowfield and signature modeling capabilities. The needs of various communities will be presented in a classified environment to facilitate meaningful discussion, and to develop advocacy for funding the capability as a national asset.

PSHS has organized 11 sessions in which 47 papers will be presented. The main areas of discussion will be Insensitive munitions (IM) technology, explosive sensitivity, gap test applications and materials, energetic liquid hazards, cook-off testing and modeling, gun propellant characterization, fragment impact testing and modeling, shock-induced reactions, and hazard classification. The IM community will be hosting two sessions with topics covering IM mitigation technologies, propellant thermal stability, and initiation reliability of IM fills. The cook-off community is looking to improve predictive tools and address decomposition parameters and how they relate to reaction violence. Modeling and simulation activities will be discussed across all areas including, but not limited to: initiation, reactive flow, deformation and failure, explosive reactive rate simulations, and gap test modeling. Monday will also include a specialist session focused on fire protection related to vehicle fires. The IM technology, Energetic Liquid Hazards, Safety/Hazard Classification, Cook-off and Shock/Impact-induced Reactions panels will also be meeting to update the community on current activities and challenges. For complete details on all the papers and topics PSHS and the other technical subcommittees will be covering, please see the meeting program soon available through the JANNAF portal at https://www.jannaf.org/node/198.

The *JANNAF Journal of Propulsion and Energetics* is seeking reviewers with knowledge of rotating detonation engine (RDE) technology.

If you are interested in reviewing RDE manuscripts, please contact:

Managing Editor Benjamin Schwantes at bschwantes@erg.jhu.edu

In Memoriam

Mr. William Lee Hoffman (1941-2017)

Mr. William Lee Hoffman passed away on July 4, 2017, at the age of 76, due to complications following open-heart surgeries to treat a bacterial infection. Hoffman served as a consultant for the Chemical Propulsion Information Analysis Center (CPIAC) (now the Johns Hopkins University, Whiting School of Engineering, Energetics Research Group) and JANNAF. He was instrumental in the development of JANNAF's *Test and Evaluation Guideline for Liquid Rocket Engines*.

Born on June 20, 1941, in Decatur, Ind., Hoffman grew up in the nearby community of Monroe, where his family ran a gas station. He attended Purdue University and graduated with a B.S. in mechanical engineering with a focus on rocket propulsion. After graduation, he secured an engineering position with Aerojet General (now Aerojet Rocketdyne) in Sacramento, Calif. Over the next 44 years, Hoffman served as an engineer on numerous rocket development programs including Titan and Delta. He also served as a program manager for various projects at Aerojet. Hoffman later took on a marketing role and specialized in promoting Aerojet's liquid propulsion rocket engine technologies at an international level. After his retirement in 2006, he continued to consult for the rocket propulsion community.

During his spare time, Hoffman engaged in a number of hobbies including car racing, astronomy, travel, and fine dining. He and his friends enjoyed building super modified sprint cars and Hoffman served as the engine builder for the group. He also volunteered his time repairing cars for those who were unable to, or could not afford to, do it themselves.

Hoffman is survived by his wife of 26 years, Jo Ann, and daughters Debbie Luz and Terri Hoffman, as well as grandchildren and one great-grandchild.

In Memoriam

Dr. R. Jeffrey Balla passed away in late June 2017 at the age of 59. A staff scientist in the Instrument Research Division at NASA Langley Research Center (LaRC), Balla was active in the JANNAF community and served as the Combustion Mission Area V Chair (Combustion Diagnostics) for the Combustion Subcommittee, as well as a panel chair for the Flowfield Diagnostics Panel and a workshop chair for a 2005 "Diagnostics for Hydrocarbon Combustor" workshop. He also shared his research on flowfield diagnostics at various JANNAF meetings.

A native of Glen Lyon, Pa., Balla received a B.S. from Muhlenburg College and later a Ph.D. in physical chemistry from Penn State University. After obtaining his doctorate in 1985, Balla served as a postdoctoral fellow at the Naval Research Laboratory in Washington, D.C., and the National Energy Technology Laboratory in Morgantown, W.Va. He began work at NASA LaRC in 1988 and developed laser-based measuring techniques for conducting flowfield research on wind tunnel models. In addition to his work at LaRC, Balla served as an adjunct professor of physics at Old Dominion University in Norfolk, Va. During his career, he authored more than 70 journal articles, conference papers, and invited lectures about his flowfield research.

Dr. Balla enjoyed spending free time on his farm in Fairmount Township, Pa., and was an active member of St. John's Slovak Lutheran Church in Nanticoke, Pa., and the Nanticoke Lodge #332 of the Free and Accepted Masons. He is survived by his sister, Jane Walker, and his extended family.

Specialist Session Focuses on Creating a World-Class Safety Culture

Mr. Stanley Graves, Orbital ATK's Senior Director, Mission Success, presented an insightful analysis of dysfunctional and successful safety cultures in public and private institutions over the past few decades in a specialist session at the May 2017 JANNAF Meeting. In an afternoon session chaired by David E. Richardson of Orbital ATK, Graves first discussed the 1986 Challenger and 2003 Columbia Space Shuttle disasters and what both events revealed about NASA's safety culture at the time. Later, he addressed the lessons learned from other unmanned launch vehicle failures in the 1990s. Finally, he discussed industrial accidents and the processes that could be used to better understand their root causes and successfully implement systemic solutions.

Based on his experience as Chief Engineer for the Space Shuttle Solid Rocket Motor, Graves discussed the development of the Solid Rocket Boosters (SRBs) for the Space Shuttle program from a successful, flight-tested Titan IIIC solid rocket booster design. He noted that necessary design changes led to unanticipated issues with the new SRBs as testing showed that the field joints between SRB segments were dynamic rather than fixed during SRB firings, which could allow o-rings in the joints to lose contact with mating surfaces and permit hot gas to exit the joints during flight. Despite this problem, NASA officials concluded in 1980 that the SRB design had an adequate safety margin and that the success of the Titan IIIC program had demonstrated the fundamental reliability of the booster design. Early launches of the Space Shuttle, however, revealed problems with the SRB field joints, as primary o-rings were found to have been eroded by hot gases during SRB firings on a number of flights. Post-flight analysis of the SRBs following a cold-weather launch (53 degrees Fahrenheit) in January 1985 revealed that secondary o-rings in two field joints had experienced heat effects. Nevertheless, NASA officials felt that this was acceptable since the secondary o-rings had functioned properly and had contained the hot gases within the booster. Thus, as Graves highlighted, deviance from design specifications was considered acceptable since the problem appeared to be self-limiting and cold-weather launches from the Kennedy Space Center in Florida were deemed exceedingly rare. The Challenger launch a year later demonstrated the fallacy of these assumptions. With an ambient temperature at launch of 28 degrees Fahrenheit, a secondary o-ring in one of the field joints in the right SRB failed at launch and again when the launch vehicle reached the point of maximum dynamic pressure (Max Q), allowing hot gas to escape, which damaged a strut connecting the SRB to the external fuel tank, leading to a chain reaction that tore apart the fuel tank and orbiter. Post-accident investigations revealed that engineers' assumptions about the performance of the o-rings in the field joints were flawed and did not reflect the actual physical performance of the components when in flight. Similarly, NASA program managers failed to appreciate the systemic risk posed by the problems with the field joints, particularly the impact of temperature on o-ring function, which was not well understood by the SRB engineering team at the time, and under pressure to maintain an intense launch schedule, sought reasons to fly missions instead of reasons to postpone them.

Stanley Graves' review of the 2003 Space Shuttle Columbia accident similarly demonstrated NASA officials' failure to recognize the true systemic risk posed by foam loss from the Shuttle's external fuel tank at launch because past instances of foam loss had not caused "safety of flight" damage to the orbiter. Having participated in the formal flight readiness review for the Columbia mission, Graves noted that a culture of silence existed within NASA and that participants from various elements within the Shuttle program would not challenge the conclusions made by other elements of the program. Mission officials were aware that foam loss could pose a threat to the Shuttle orbiter, but concluded, with questionable justification, that the threat was manageable and would not affect the Columbia launch. Even after post-launch inspection revealed a foam strike on the Shuttle's wing, NASA officials failed to appreciate

(continued on page 8)

JANNAF Holds May 2017 Meeting in Kansas City, Missouri

Kansas City, Mo., provided the setting for the 64th JANNAF Propulsion Meeting, the JANNAF Programmatic & Industrial Base (PIB) Meeting, and the 44th Structures and Mechanical Behavior (SMBS), 40th Propellant and Explosives Development and Characterization (PEDCS), 31st Rocket Nozzle Technology (RNTS), and 29th Safety and Environmental Protection (SEPS) Joint Technical Subcommittee Meeting. Dr. Charles J. Trefny, NASA Glenn Research Center, Cleveland, Oh., chaired the meeting, which included a keynote address and panels, workshops, and specialist sessions hosted by the subcommittees in attendance.

Mr. Bruce K. Tiller, Deputy Manager of the Space Launch System (SLS) Solid Rocket Boosters Office in the NASA Space Launch System Program at NASA Marshall Space Flight Center, Huntsville, Ala., presented an informative keynote address that focused on NASA's SLS and how it would serve as a stepping stone for exploration of Mars in the 2030s. Tiller showed a video that offered an overview of the SLS program and the development of the SLS heavy-lift rocket and Orion spacecraft. He then discussed NASA's phased approach to deep space exploration, which involves establishing a Deep Space Gateway in cislunar space in the 2020s, assembling a Deep Space Transport vehicle, and then departing from the Gateway for Mars by the early 2030s. The SLS will provide NASA with a heavy-lift capacity and will be tasked with transporting astronauts and equipment beyond low earth orbit (LEO). The vehicle consists of a central core stage containing fuels tanks, engines, an upper stage, and the Orion spacecraft, and two large solid rocket boosters (SRBs). The SLS will reuse various components from the Space Shuttle program such as the RS-25 Space Shuttle Main Engines and segments from the Space Shuttle SRBs. As Tiller noted, this approach will provide time for NASA to improve manufacturing technologies and practices in order to produce lower-cost versions of the RS-25s and the SRBs for future launches once the current supply is expended. Tiller concluded his presentation by emphasizing that

Keynote speaker Mr. Bruce K. Tiller, Deputy Manager of the SLS Solid Rocket Boosters Office in the NASA Space Launch System Program at NASA Marshall Space Flight Center, Huntsville, Ala.

with all the groundbreaking work going on at NASA, it is "a really exciting time to be [at the space agency]." He reminded the audience that "lots of work [is] going on… that's the message I'm trying to give you here." Tiller concluded the presentation by taking questions from the audience regarding the SLS and Mars exploration. Following Tiller's keynote address, Mr. Drew DeGeorge of the JANNAF Technical Executive Committee (TEC) promoted the *JANNAF Journal* and encouraged attendees to consider submitting papers to the limited-distribution publication. After DeGeorge spoke, Dr. Christine Michienzi, Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, the Department of Defense (DoD) co-chair of the PIB, introduced Mr. Michael H. Kynard, Deputy Director of the NASA Michoud Assembly Facility, as the new NASA co-chair for the PIB, and spoke briefly about the PIB's role within JANNAF and its relationship to the JANNAF TEC.

The four JANNAF technical subcommittees that met in Kansas City held many interesting and informative workshops, panels, and specialist sessions during the four-day meeting. SMBS and RNTS jointly hosted

(continued on page 9)

Creating a World-Class Safety Culture... *continued from page 6*

the gravity of the situation and concluded that the mission should proceed as planned. Graves argued that if mission officials had better quantified the risk of foam strikes on the Shuttle through a physics-based understanding of the problem, much like their failure to understand the fundamental physics of o-ring behavior in the SRB field joints, they would have recognized the true threat posed by the problem and delayed the launch. Graves concluded this portion of his presentation by discussing a set of "Flight Rationale Elements" that he introduced at NASA following the Columbia accident. These elements helped project managers better understand and assess the risks associated with various elements of the Shuttle program and make educated, physics-based safety assessments of future space launches.

In the second part of his talk, Graves discussed the lessons learned from his paticipation in the Broad Area Review that examined five rocket launch failures in the late 1990s. As with other aerospace accidents, workmanship was assumed to be a major contributor to the launch failures. However, the review found that manufacturing and shop floor practices represented only a small portion of the overall source of blame for the failures. Instead, problems inherent to the rocket design process and systems engineering issues were the major sources of launch vehicle failures. Critical engineering errors were overlooked. Engineers failed to communicate design intent to technicians on the shop floor. Materials and processes were altered during the manufacturing process without proper documentation and approval by the engineering staff. These types of errors, Graves noted, must be anticipated and addressed through proper independent reviews and other methods of maintaining accountability.

Mr. Stanley Graves, Orbital ATK Senior Director, Mission Success, discusses workplace safety cultures in an SMBS- and RNTS-sponsored specialist session.

In the final portion of his presentation, Graves focused on industrial safety and strategies for creating a world-class safety culture. Based on his experience investigating accidents at Orbital ATK, he enumerated what he saw as the root causes of industrial accidents and presented a framework for learning from accidents and "draining the swamp" to eliminate the systemic causes of workplace incidents. As he noted, unsafe acts may be hard to foresee, but unsafe conditions can and should be identified and eliminated wherever possible. He offered a number of approaches for correcting problems beforehand, such as devising and implementing specific protocols for completing tasks; ensuring that technicians do not deviate from protocols or attempt to improvise solutions to problems; improving one's physics-based understanding of processes in order to ensure that best practices are devised and implemented; and designing equipment and work practices with an eye towards eliminating possible sources of trouble. Through these practices, Graves argued, industrial operations may be made safer and both managers and shop floor employees can internalize best practices in order to eliminate risk in the workplace.

JANNAF News is seeking short technical articles for future editions.

All articles must be Distribution Statement A / Publicly Releasable.

If you are interested in submitting an article or have any questions, please contact

Managing Editor Benjamin Schwantes at bschwantes@erg.jhu.edu

a specialist session entitled, "Creating a World Class Safety Culture – Lessons Learned from Launch Vehicle Failures and Industrial Accidents." Mr. Stanley Graves, Orbital ATK's Senior Director, Mission Success, offered his unique perspective on how to create a world-class safety culture within public and private organizations. As Chief Engineer for the Space Shuttle Solid Rocket Motor, Graves was intimately involved in both the Challenger and Columbia disasters investigations, and supported the Broad Area Review that investigated systemic causes of five unmanned launch vehicle failures in the late 1990s. As Vice President of Safety and Mission Assurance at Orbital ATK, he was assigned as accident investigation chairman for an explosion that led to a fatality. He also lived through and scrutinized a myriad of other industrial accidents, fires, and explosions. Initiatives that Graves helped put in place reduced the Total Recordable Rate (TRR) from 1.8 to a world-class 0.80. From his experiences, the causes of calamities are generally obvious within a few hours or days of the disaster. If easily seen after the fact, the underlying issues should be readily apparent before disaster strikes. Mr. Graves shared his methodology for identifying organizational and cultural risks, and he outlined specific initiatives that can be undertaken to prevent crisis and create a healthy, high-performing safety culture. The session generated a significant amount of interest within the technical community and offered a new generation of engineers important safety lessons based on historical experience. Much of the technical community is interested in learning from past experience, so RNTS and SMBS plan to continue to identify possible contributors to share lessons learned from historical efforts at future meetings. For more on Graves' specialist session, see page 6.

SMBS and RNTS also jointly held a workshop on "Verification, Validation, and Uncertainty Quantification," moderated by Dr. David Richardson, Mr. David Black, and Dr. Brian Liechty of Orbital ATK. The objective of the workshop was for SMBS and RNTS members to work in conjunction with Modeling and Simulation's Verification, Validation, and Uncertainty Quantification Team, headed by Dr. Unmeel Mehta of NASA Ames Research Center (ARC) and Dr. Dean Eklund of the Air Force Research Laboratory (AFRL), to define approaches for verification, validation, and uncertainty quantification that can be used in the propulsion analysis community, with a particular emphasis on rocket nozzle technology and structures and mechanical behavior. This year's workshop focused on: 1) presenting and reviewing approaches being utilized currently; and 2) developing a team of industry experts in SMBS and RNTS who will develop examples of applications of approaches and present to the JANNAF community outcomes of simulation credibility assessments. The level of interest in the workshop highlighted its success. Richardson stated that one of the goals they were planning to accomplish was to "start the technical community in thinking about the ability to design solid rocket motors using non-deterministic approaches. Uncertainty quantification is a hard pill to swallow for many engineers, but analytical capabilities have been demonstrated on several solid rocket motor applications. This approach could revolutionize how nozzles are designed." When asked about the path forward, Richardson replied, "Aid in firming up of standardized UQ analytical techniques. Work collaboratively with the [MSS] on verification and validation. There needs to be a standardization of the analytical techniques."

RNTS held a workshop on "Advanced Thermal Structural Modeling of Carbon Cloth Phenolic" moderated by Dr. Richardson of Orbital ATK, and organized with the assistance of Mr. Jeppy Louie Clayton of NASA Marshall Space Flight Center. The purpose of the workshop was to develop an industry-accepted, physics-based, non-linear, fully integrated coupled thermal and structural material model for accurate prediction of the response of heated phenolic material used in ablative thermal protection systems. Currently, many of the thermal/structural models have been empirically based, involving approximations for the complex nonlinear nature of the material response of heated pheno-

(continued on page 14)

Rocket Planes in the High Desert

In honor of the fifth anniversary of Astronaut Neil Armstrong's death, Milton B. McKay, whose father flew alongside Armstrong in the X-15 hypersonic research program during the early 1960s, reflects on growing up near Edwards Air Force Base and his early encounters with the man who would later command the Apollo 11 mission to the Moon.

It wasn't until I was in the second or third grade in an elementary school in Lancaster, California, in the early 60s, that I finally realized what my father did at work. I knew he was gone every morning before I woke up for school with Mom preparing our breakfast while "glued" to the local radio station that announced activity at Edwards Air Force Base.

One day at school, I saw him on a film my teacher was showing our class about the "goings-on's" at the NASA Facility at Edwards Air Force Base. The film was about the X-15 Program and showed Dad climbing into the cockpit of an X-15 Research Rocket Plane. Wow! Now I know!

My father, John B. McKay, began his career in February 1951 at what was once known as the "High Speed Flight Research Station" and the National Advisory Committee for Aeronautics (NACA), prior to being redesignated to NASA. He graduated from Virginia Polytechnic Institute after serving as a Navy pilot in WWII. He flew most of the early X-Planes through the early years and became the fifth of twelve pilots chosen to fly the X-15. Then, in July of 1955, another Navy pilot by the name of Neil Alden Armstrong came on the scene at the young age of 25.

For the next several years, Dad, Neil, and the other pilots assigned to the program traded off on flying the main research aircraft for the daily mission, or flew chase, or were part of flight control crew in the Control Room. In 1958, both Neil and my father were selected for the U.S Air Force's" Man in Space Soonest Program." An unsubstantiated source reported three pilots from the X-15 Program were considered for the Apollo Program and eventually the Moon shot: Neil Armstrong, John McKay, and Joseph Walker. I believe Neil joined the NASA Astronaut Corps in 1962.

Over time, this small, elite group of twelve men and their families slowly grew together in rural Antelope Valley, having backyard BBQs and camping outings in the Tehachapi Mountains. Some of the pilots, John McKay and Joe Walker, for example, would hike the John Muir Trail to Mt. Whitney in the Sierra Nevada and have a couple of pilots make supply drops along the way. Growing up, I had the pleasure of knowing four or five of the X-15 pilots more than the others. One being Mr. Neil Armstrong. Neil was known, as the story goes anyway, for owning five cars, four in the shop and one for driving to work. One of my most memorable meetings with Mr. Armstrong occurred on a Saturday morning in 1962. The pilots and ground crew for the X-15 had a flight party on a Friday night. I learned over the years that they didn't necessarily have to have a "flight" to celebrate, but I'm sure they did in this case. So, come closing time at the "Club Le-Basque," Neil couldn't get home, perhaps because his car wouldn't start, or for some other reason. Dad offered to let him sleep at our house that night and said they'd take care of his car the next morning. Saturday morning was a ritual for me! I would get out of bed, go to the front porch to get a bottle of milk, proceed to the kitchen, and make my cereal. Then, I would put the bottle of milk back on the porch. On this particular Saturday, I proceeded to the master den and turned on the RCA TV to warm up to watch "Looney Tunes"! I turned around to the leather couch and said…. "Mr. Neil, could you scoot your feet back just a little so I can sit and watch cartoons"! I saw a smiling face on a man who obliged and we watched Buggs Bunny and Yosemite Sam!

Neil Armstrong (left) and the author's father, John B. McKay (right) stand in front of a North American X-15 rocket plane at Edwards Air Force Base in the early 1960s. (NASA)

John B. McKay being greeted by officials after a successful X-15 flight. (NASA)

Six pilots from the X-15 program pose in front of the aircraft. John B. McKay is the second from the left in the photograph and Neil Armstrong is the second from the right. (NASA)

1962 accident in which John B. McKay was severely injured while attempting to land a malfunctioning X-15 at Mud Lake, Nevada. (NASA)

X-15 pilots Milton O. Thompson (left), William H. Dana (center), and John B. McKay (right). (NASA)

65th JPM / PIB / 12th MSS / 10th LPS / 9th SPS to Meet
21–24 May 2018

Long Beach Hilton
Long Beach, Calif.

Questions

Technical questions may be addressed to the following ERG technical representatives:

- JPM – Peter Zeender (pzeender@erg.jhu.edu / 443-718-5001)
- PIB – Kirk Sharp (ksharp@erg.jhu.edu / 228-234-5423)
- MSS – Alex Bishop (abishop@erg.jhu.edu / 443-718-5008)
- LPS – Ben Hill-Lam (bhill-lam@erg.jhu.edu / 443-718-5011)
- SPS – David Owen (dowen@erg.jhu.edu / 443-718-5006)

For all other meeting-related matters, please contact Shelley Cohen (scohen@erg.jhu.edu / 410-992-7302).

Why should you sponsor the JANNAF Journal?

The JANNAF Journal of Propulsion and Energetics is an established technical resource for qualified U.S. citizens of the propulsion and energetics community. It is complimentary to all U.S. Government organizations, ERG subscribers, and qualified JANNAF meeting attendees.

The JANNAF Journal contains only limited-distribution, peer-reviewed material, and provides scientists, researchers, and other technical professionals the opportunity to share information that would otherwise go unpublished.

Sponsoring the journal allows your company or organization to gain widespread exposure within the propulsion community, and demonstrates your commitment to the industry. Your sponsorship helps support technological advancement in aerospace propulsion and energetic materials research and development.

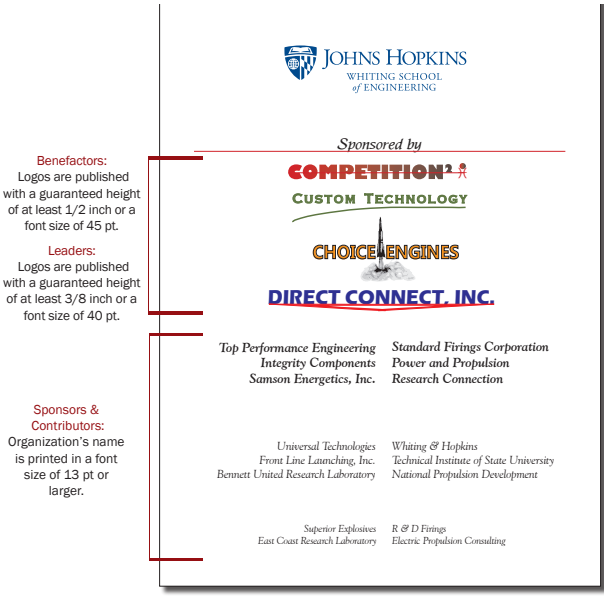
All sponsors are acknowledged on the back cover of the journal, on the journal website, and at JANNAF meetings.

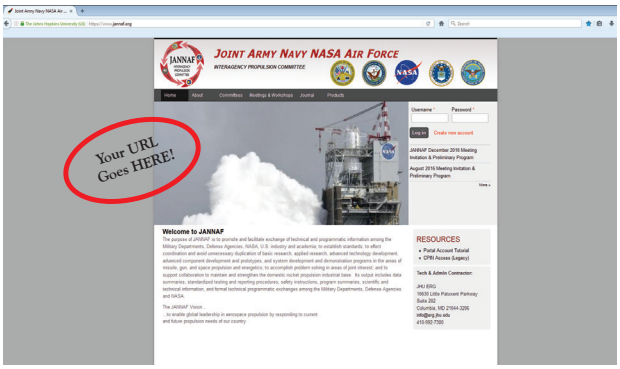
Depending on the level of sponsorship you choose, this acknowledgment could include your organization's logo.

A listing of all sponsors is featured on the JANNAF website, with company names hyperlinked.

Discounted rates are available for multiyear commitments.

For more information, download the sponsorship guide at www.jannaf.org or email JANNAFjournal@erg.jhu.edu.





JANNAF Journal of Propulsion and Energetics

The Call For Papers is Ongoing

Submit your manuscript NOW for consideration in

Volume 10

For questions on....

manuscript style or preparation, figures and graphics, submission procedures, and deadlines

Contact Journal Managing Editor Benjamin Schwantes at Bschwantes@erg.jhu.edu

For matters related to....

technical topics, special focus areas, research, and data

Contact Technical Advisor David Owen at JournalTA@erg.jhu.edu

JANNAF May 2017 Meeting... *continued from page 9*

Dr. Christine Michienzi, DoD co-chair of the PIB and Mr. Michael H. Kynard, the new NASA co-chair of the PIB.

Dr. Sara K. Pliskin accepts award from Dr. Mark S. Johnson on behalf of Dr. Randall J. Cramer recognizing Dr. Cramer's support of SEPS.

lic material. Most models have had a loose/independent coupling of the thermal and structural models. These models tend to cause designers to overdesign systems, particularly for man-rated systems. The objective of this workshop was to discuss the status of development of advanced codes (improvements and applications since the last workshop) and to share applications where use of the advanced model would have been, or has been, useful. Richardson commented, "This is a good forum for very technical people to discuss this important topic, as there are not many people who understand the issues. Much of the upcoming generation is not aware of the subtleties of thermostructural modeling and need an education." RNTS plans on continuing this collaborative approach to develop advanced modeling techniques and to educate the community.

PEDCS held a total of 21 sessions spanning 4 days. There were 116 presentations given within the PEDCS mission areas covering a wide range of topics. (A summary of each session is provided with more detailed information available in the meeting program.) There were three specialist sessions dedicated to the additive manufacturing (AM) of energetics and energetic devices. These provided attendees with agency specific topics of research. All DoD agencies, as well as a number of national laboratories, were represented. Research discussed ranged from evaluating off-the-shelf printer/additive manufacturing technologies for use in the manufacture of energetic materials to the understanding of fundamental material properties associated with a number of AM processes. Also discussed was modeling of AM processes and how variations in materials affect the processes.

PEDCS held two processing sessions and noted that AM and resonance acoustic mixing (RAM) had garnered considerable interest, which continues to grow. Members of the community highlighted three processing topics of particular interest at the JANNAF Meeting, which should continue to attract more and more attention at future meetings. These included: (1) AM, (2) RAM, and (3) advanced flow reactor (AFR) technologies.

Topics discussed during the advanced testing and materials session included the comparison of laser-induced plasmas and electrostatic discharges for the deflagration of energetic materials, modeling of electromagnetic heating, subscale arena testing for insensitive munitions (IM) formulations, and the IM response of numerous energetics.

Other highlights of the meeting included the characterization of aged hydroxyl-terminated polybutadiene (HTPB) reactivity, nuclear magnetic resonance (NMR)

(continued on page 15)

analysis of HTPB, and the use of gas chromatography-mass spectrometry (GCMS) in propellant characterization. Sessions focused on process development, pilot-scale manufacturing, modern continuous manufacturing of certain explosive ingredients, and explosive formulation, which covered formulation, production, and characterization of a number of propellants. Novel explosives research focused on the synthesis and characterization of melt-cast, high-energy, and improved IM explosives.

Topics on sensitivity testing and shock physics included enhanced super-large-scale gap test, numerical study of donor-acceptor interface designs, laser-driven flyer plates, shock sensitivity, combined CYLEX/DAX testing for very large diameter explosives, development of minimum signature propellants, and the evaluation of protocols used to determine shock sensitivity.

PEDCS held a kickoff meeting with the goal of updating the Navy's Explosive Security Classification Guide. With key participants already at the JANNAF Meeting, the meeting provided an opportunity to gather the appropriate subject matter experts and begin the process of reviewing and updating the document. The goal of the meeting was to formalize key Joint Service stakeholders and develop the roadmap and Plan of Action & Milestones (POA&M) for the update of the *Explosives and Propellant Security Classification Guide*.

SEPS held a total of 4 well-attended sessions during the JANNAF Meeting, which contained 18 presentations related to the safety, health, and environmental impacts associated with the manufacture, storage, and use of propellants, explosives, and pyrotechnics. Topics ranged in scope from discrete effects of energetic materials on fish larvae to the progress being made in demilitarization of multiple-launch rocket systems (MLRS) and their submunition payloads.

In addition to moderating technical sessions, the newly elected Subcommittee Chair, Dr. Sara K. Pliskin of the Naval Surface Warfare Center (NSWC) Crane Division, chaired two panel sessions, co-chaired one technical session, and co-chaired one joint panel session with PEDCS. The SEPS Technical Steering Group meeting enabled the subcommittee to continue to refine its structure and membership to reflect recent guidance from the JANNAF TEC. All SEPS activities benefited from the transitional support of the outgoing Subcommittee Chair, Dr. Mark S. Johnson, Army Public Health Center, Aberdeen Proving Ground, who remains active in the group and continues as a member of the Technical Steering Group.

Demilitarization, reclamation, and reuse technologies topics included presentations that detailed the progress of ammonium perchlorate and liquid rocket motor destruction programs, the development of a water-cooled band saw, and the status of the MLRS warhead demilitarization program. Toxicology-related presentations addressed in vitro effects of exposure to energetic materials, and various compounds' effects on rats, fish, and birds. Additionally, Dr. David Mattie, 711th Human Performance Wing, Wright-Patterson Air Force Base, moderated a successful toxicology and occupational health panel meeting. Presentations related to environmental aspects of munitions included updates for the Revised Toxic Substances Control Act, investigation into photo-degradation of traditional and insensitive explosives, and the introduction of an online resource for energetics contamination on military training ranges. Dr. William Eck of the Army Public Health Center, Aberdeen Proving Ground, moderated a panel meeting on aspects of environmental protection consideration during the full life cycle of DoD energetics programs.

SEPS and PEDCS together presented a technical session on "Green Energetic Materials," which focused on the development of environmentally sustainable energetic ingredients, formulations, and processing technologies. The development of novel insensitive munitions-standards-compliant Comp B replacements, improvements in continuous manufacture of DBX-1, and reduction of lead in various explosive compound formulations were discussed at length, and a panel meeting on "Green Energetic Materials" was moderated by Dr. Noah Lieb of Jensen Hughes, Baltimore, Md.

ERG Directory

DIRECTOR

Peter E. Zeender
pzeender@erg.jhu.edu / 443-718-5001

CUSTOMER SERVICE

General Inquiries
410-992-7300

Technical Inquiries
410-992-7301

Administrative Staff

Debbie Eggleston
Administrative Manager
dse@jhu.edu / 443-718-5002

Meetings

Shelley Cohen
JANNAF Meeting Manager
scohen@erg.jhu.edu / 410-992-7302

Kathleen Rowan
JANNAF Meeting Planner & Proceedings Editor
krowan@erg.jhu.edu / 410-992-7300 ext. 208

Security

Mary Gannaway
Facility Security Officer
mtg@jhu.edu / 410-992-7304 ext. 211

Tricia Reider
Assistant Facility Security Officer
treider@erg.jhu.edu / 410-992-7300

INFORMATION TECHNOLOGY

Bruce Dennett
IT Manager
bdennett@erg.jhu.edu / 443-718-5003

Valerie Dixon
LAN Administrator
vdixon@erg.jhu.edu / 410-992-7304 ext. 203

Paco Wong
Software Engineer
pwong@erg.jhu.edu / 410-992-7307

COMMUNICATIONS AND PUBLICATIONS

Linda McLean
Communications and Publications Group Manager
lmclean@erg.jhu.edu / 410-992-7304 ext. 225

Benjamin Schwantes
JANNAF Journal Managing Editor
bschwantes@erg.jhu.edu / 410-992-7300 ext. 227

TECHNICAL REPRESENTATIVES

Tom Alsbrooks
talsbrooks@erg.jhu.edu / 443-718-5012
Bill Bagley
wbagley@erg.jhu.edu / 443-718-5009
Alex Bishop
abishop@erg.jhu.edu / 443-718-5008
Bryan DeHoff
bryan.dehoff@aerospacetechnic.com / 513-378-7071
Ben Hill-Lam
bhill-lam@erg.jhu.edu / 443-718-5011

Nicholas Keim
nkeim@erg.jhu.edu / 443-718-5005
David Owen
dowen@erg.jhu.edu / 443-718-5006
Kirk Sharp
ksharp@erg.jhu.edu / 228-234-5423
Andrew Taylor
ataylor@erg.jhu.edu / 443-718-5007

JANNAF Technical Executive Committee

CHAIRMAN

Dr. Brad E. Forch
U.S. Army Research Laboratory/APG

ARMY

Dr. Jay S. Lilley
U.S. Army AMRDEC/Redstone Arsenal

NAVY

Dr. Jeffery J. Davis
Naval Air Warfare Center Weapons Division/China Lake

Mr. Frank C. Tse
Naval Surface Warfare Center/IH

NASA

Dr. Thomas M. Brown
NASA Marshall Space Flight Center/Huntsville

Dr. Dhanireddy R. Reddy (D.R.)
NASA Glenn Research Center/Cleveland

AIR FORCE

Mr. Drew O. DeGeorge
U.S. Air Force Research Laboratory/EAFB

Mr. Robert A. Mercier
U.S. Air Force Research Laboratory/WPAFB

EX OFFICIO

Mr. Andrew S. Culbertson
ODDR&E/OUSD(AT&L)/Washington, D.C.

Mr. Garry M. Lyles
NASA Headquarters/Washington, D.C.

JANNAF Programmatic & Industrial Base Executive Committee

CO-CHAIRS

Dr. Christine Michienzi
OSD (AT&L) (MIBP)/Washington, D.C.

Mr. Michael H. Kynard
NASA Marshall Space Flight Center/Huntsville

ARMY

Dr. Brad E. Forch
U.S. Army Research Laboratory/APG

Dr. Jamie B. Neidert
U.S. Army AMRDEC/Redstone Arsenal

Mr. David L. Tritt
U.S. Army PEO (M&S)/Redstone Arsenal

NAVY

Mr. Shahab U. Chaudhry
Navy Strategic Systems Program/Washington, D.C.

Mr. Frank C. Tse
Naval Surface Warfare Cente/IH

NASA

Ms. Mary Beth Koebl
NASA Marshall Space Flight Center/Huntsville

Mr. Alex S. Priskos
NASA Marshall Space Flight Center/Huntsville

Dr. George R. Schmidt
NASA Glenn Research Center/Cleveland

AIR FORCE

Lt. Col. Paul Adamson
U.S. Air Force (A10)/Washington, D.C.

Mr. Drew O. DeGeorge
U.S. Air Force Research Laboratory/EAFB

Mr. Harry C. DuRette
U.S. Air Force SAF (AQ)/Chantilly

Mr. Thomas Ganey
U.S. Air Force Research Laboratory (RX)/Washington, D.C.

Lt. Col. David Rondeau
U.S. Air Force SAF (SPA)/Washington, D.C.

DEPARTMENT OF DEFENSE

Mr. Andrew S. Culbertson
ODDR&E/OUSD(AT&L)/Washington, D.C.

Mr. David Jerome
DLA (Energy Aerospace)/San Antonio

Mr. Douglas G. Smith
DLA (Energy Aerospace)/San Antonio

JANNAF Subcommittee Chairmen and ERG Representatives

Subcommittee/Chair	Deputy Chair	ERG Representative
AIRBREATHING PROPULSION (APS)		
Mr. Lawrence D. "Larry" Huebner NASA Marshall Space Flight Center	**Dr. James W. Weber** Air Force Research Laboratory/WPAFB	**Mr. Bryan DeHoff**
COMBUSTION (CS)		
Dr. Heather F. Hayden Naval Surface Warfare Center/IH	**Dr. Ghanshyam L. Vaghjiani** Air Force Research Laboratory/EAFB	**Mr. Bryan DeHoff**
EXHAUST PLUME and SIGNATURES (EPSS)		
Dr. Milton E. Vaughn Jr. U.S. Army AMRDEC/Redstone Arsenal	**Dr. Manish Mehta** NASA Marshall Space Flight Center	**Mr. Nicholas Keim**
LIQUID PROPULSION (LPS)		
Mr. James L. Cannon NASA Marshall Space Flight Center	**Dr. Daniel L. Brown** Air Force Research Laboratory/EAFB	**Mr. Ben Hill-Lam**
MODELING and SIMULATION (MSS)		
Dr. Michael D. Watson NASA Marshall Space Flight Center		**Mr. Alex Bishop**
PROPELLANT and EXPLOSIVES DEVELOPMENT and CHARACTERIZATION (PEDCS)		
Dr. Mark H. Mason Jr. NAWCWD-CL	**Mr. Charles L. Davis** NASA Kennedy Space Center	**Mr. Andrew Taylor**
PROPULSION SYSTEMS HAZARDS (PSHS)		
Ms. Jamie M. Fisher U.S. Army AMRDEC/Redstone Arsenal	**Mr. Adam J. Brand** Air Force Research Laboratory/EAFB	**Mr. Andrew Taylor**
ROCKET NOZZLE TECHNOLOGY (RNTS)		
Mr. John Robert Esslinger Jr. U.S. Army AMRDEC/Redstone Arsenal	**Mr. Jeppy Louie Clayton** NASA Marshall Space Flight Center	**Mr. David Owen**
SAFETY and ENVIRONMENTAL PROTECTION (SEPS)		
Dr. Sara K. Pliskin NSWC/Crane	**Dr. David R. Mattie** Air Force Research Laboratory/WPAFB	**Mr. William Bagley**
SPACECRAFT PROPULSION (SPS)		
Mr. David T. Jacobson NASA Glenn Research Center	**Dr. William A. Hargus Jr.** Air Force Research Laboratory/EAFB	**Mr. David Owen**
STRUCTURES and MECHANICAL BEHAVIOR (SMBS)		
Dr. Timothy C. Miller Air Force Research Laboratory/EAFB	**Dr. Jeremy R. Rice** U.S. Army AMRDEC/Redstone Arsenal	**Mr. David Owen** **Mr. Tom Alsbrooks**

JANNAF Programmatic & Industrial Base Working Groups

Working Group/Lead

LARGE LIQUID PROPULSION

Mr. Michael J. Klassen
The Aerospace Corp/El Segundo

SMALL LIQUID PROPULSION

Mr. Charles W. Pierce
NASA Marshall Space Flight Center

LARGE SOLID ROCKET MOTOR

Mr. Timothy W. Lawrence
NASA Marshall Space Flight Center

SMALL SOLID ROCKET MOTOR

Mr. Frank C. Tse
Naval Surface Warfare Center/IH

ELECTRIC PROPULSION

Mr. David T. Jacobson
NASA Glenn Research Center

SCIENCE and TECHNOLOGY

Mr. Drew O. DeGeorge
U.S. Air Force Research Laboratory/EAFB

TEST and EVALUATION

Mr. Clifton T. Arnold Jr.
NASA Stennis Space Center

ERG Staff Celebrate the Great American Eclipse of 2017

***JANNAF Journal* Volume 8, Issue 1**
will be available in December 2017.
Keep an eye out for it!

Rededication ceremony for the High-Pressure Combustion Laboratory at Penn State University in honor of the late Dr. Kenneth K. Kuo.

Participants in Networking Night at the May 2017 JANNAF Meeting in Kansas, City, Mo..

JHU WSE-Energetics Research Group (ERG)
1,200-square-foot Conference Facility

ENERGETICS
RESEARCH GROUP

Attributes include:

- Constructed and certified for restricted or classified meetings for up to ***60 people***
- Lobby with registration desk
- Availability of certified ERG security and administrative staff for organization and administration
- Restricted/classified material safeguarding
- Separate break-out room for up to 6 people
- Two state-of-the-art 75" LCD monitors
- Teleconferencing capabilities (unclassified only)
- Two 6' x 4' double-sided white boards
- Partial kitchen
- Complimentary parking
- Catering coordination for continental breakfast, breaks, and lunch

For more information about ERG's conference space or to make a reservation, please contact:

Debbie Eggleston at dse@jhu.edu
or visit www.erg.jhu.edu

Strategically located between Baltimore, MD and Washington, DC, the CF is adjacent to the ERG Main Office at:
10630 Little Patuxent Parkway, Suite 219
Columbia, MD 21044

MEET & ENGAGE