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JANNAF TEC Chair Brad Forch Passes Away

The JANNAF Technical Executive Committee (TEC) Chair Brad E. Forch, Ph.D., passed away suddenly in early September 2018 at the age of 63. A senior research scientist (ST) specializing in ballistics at the U.S. Army Research Laboratory (ARL), Forch joined the TEC in 2004 and began serving as its chair in 2016. He also supported production of the *JANNAF Journal of Propulsion and Energetics* and joined its Editorial Advisory Board in 2006, as well as serving as an associate editor and reviewer for numerous articles. Finally, Forch joined the JANNAF Programmatic and Industrial Base Executive Committee (PEC) in 2015 as the Army Representative.

Born in Chicago, Ill., in 1955, Forch attended Illinois State University, where he received a Bachelor of Science degree in chemistry and a Master of Science degree in physical chemistry in 1978 and 1979, respectively. He went on to earn a doctorate in physical chemistry/chemical physics from Wayne State University in 1984. During his time at Wayne State, he published 10 papers on vari-

Brad E. Forch, Ph.D. (1955-2018)

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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.

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Recent ERG Publications

PROCEEDINGS

- Abstract Number: 2017-011
  Joint Orbital ATK (now Northrop Grumman Innovation Systems) and JANNAF Interagency Propulsion Committee - Simulation Credibility Guide Development Workshop
  Sep 2017

- Abstract Number: 2017-010
  Large-Scale Scramjet Engine Development Working Group - JANNAF APS Workshop
  Dec 2017

- Abstract Number: 2018-0001
  Meeting Proceedings from the "65th JPM / PIB / 12th MSS / 10th LPS / 9th SPS Joint Subcommmittee Meeting (Long Beach, Calif.)
  May 2018

- Abstract Number: 2018-0002
  JANNAF PEDCS Workshop on Additive Manufacturing of Energetic Systems
  Apr 2018

- All meeting proceedings are available in the JANNAF Digital Online Collection (JDOC) database, accessible through the JANNAF website (https//www.jannaf.org/).

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Brad Forch Obituary... *continued from page 1*

ous topics including radiationless processes in excited electronic states and Van der Waals clusters.

Following the completion of his doctoral studies, Forch served as a National Research Council postdoctoral fellow at the Ballistic Research Laboratory (BRL) at Aberdeen Proving Ground (APG), Md., where he conducted research involving laser spectroscopy of various ignition and combustion processes. In 1986, he was hired as a civilian employee at the BRL and continued his ignition research, which led to the discovery of a new laser-based resonant ignition mechanism. Between 1986 and 1994, Forch was involved with transitioning his groundbreaking research into practical applications for the Army, which helped to spur new research and development efforts, including 25 Small Business Innovation Research (SBIR) programs. He subsequently published 20 journal articles, 28 technical reports, and more than 100 technical publications. He also received an Army Science Conference award for the discovery of Ultraviolet Laser Resonant Multiphoton Ignition in 1990 and an Army Research and Development Achievement Award for Laser Ignition for Gun Propulsion in 1992.

In 1994, Forch was named Chief of the Propulsion Science Branch of the newly created ARL and began overseeing the work of approximately 60 fellow scientists. He led and supported ballistics and energetics research efforts, with a particular emphasis on understanding the chemical and physical mechanisms responsible for chemical energy storage and release in propellants and energetic materials. He received a second Army Science Conference award in 1998 for his efforts to develop laser-based igniters, an outgrowth of his own research on laser spectroscopy, combustion, and ignition behavior. Other awards of note during his time as Chief of the Propulsion Science Branch included an official commendation from "Innovations in American Government" from the Ford Foundation and JFK School for Government, Harvard University, for technology transfer (Jaws-of-Life) from SBIR (1996); a Performance Award for establishing an Army Strategic Research Objective, Insensitive High-Energy Materials (1998); APG Supervisor of the Year, awarded by the APG Federal Woman's Program (2003); the Army Research and Development Achievement Award for Leadership in Energetic Material Research (2006); and the Silver Medal, Outstanding Supervisor, Federal Executive Board (2007).

In January 2009, Forch was promoted to the elite status of ST for ballistics in the Weapons and Materials Research Directorate, a position he held until his death in 2018. Fewer than 500 STs are active in the federal government and the position merits the same status as a one-star general officer for protocol purposes. He was also named an ARL Fellow in recognition of his "exceptional technical accomplishments, reputation, [and] the prospect of continued productivity…" as the ARL Fellow website notes.

Despite his many professional responsibilities, Forch made time to support ongoing research and development efforts in the propulsion and energetics fields through his support of the *JANNAF Journal* and his leadership roles in the PEC and TEC.

"I have known Brad Forch for many years, and in many capacities – as a researcher when I was with the Navy, within the JANNAF Executive structure, and as a personal friend and mentor," Christine Michienzi, Ph.D., and JANNAF PEC co-chair, recalled. "Brad's energy and willingness to help were legendary. I frequently got emails from Brad at all hours of the day and night – weekdays and weekends. He was always keeping me, and many others in his inner circle informed of the latest news within Army and DoD senior leadership. He gave his time selflessly and many people I know benefited tremendously from knowing him – myself included.

Brad and I first worked together on novel gun propellants – he was a big supporter and collaborator. He became legendary for his 'Brad Forch' slides – very colorful and informative slides that had so much information packed into them, in an extremely creative way, that you could tell it was one of his slides the minute you saw it. Brad was also a force within the JANNAF community – serving on Steering Groups and the Executive Committee for decades, and serving as the COR for the DTIC contract for many years. I have also been involved in JANNAF for a long time, on both the technical side, and

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Brad Forch Obituary... *continued from page 3*

now as the co-chair of the Programmatic and Industrial Base Committee, and Brad always provided a stabilizing force, as well as a treasure trove of historical information and insight as JANNAF continued to move forward.

Brad also quickly became a friend, and someone I leaned on heavily as a mentor as my career progressed. He was always very interested in how my career was going (often sending me job announcements that he thought I should apply for), and he provided a lot of sage advice whenever I encountered issues, or just needed someone to bounce an idea off of or to talk to. The last email I got from him was the day he passed away, and it makes me very sad that I will never have the chance to respond to him. I join many others in saying that I will miss him tremendously."

Similarly, Robert Mercier of the TEC described Forch as "a friend and natural mentor to many in the JANNAF community. I had the pleasure of working with him for many years on the [TEC]. Whenever there were questions about policy or proper procedures, Brad would dig into the issue and find the exact wording on the topic. He was tireless in helping ARL and JANNAF. He served as an associate editor and reviewer for many *JANNAF Journal* manuscripts. He worked diligently to ensure the highest quality for the manuscripts that were published. If he wasn't the right expert, he could always give us names of other experts to review submissions to the journal. Like all of us who do those extra volunteer jobs, he would occasionally get behind on a particular review. When he got a reminder via email, he would get back to the review and complete it quickly. The community could always count on Brad for going the extra mile. We will all miss him."

Forch is survived by his sister, Katherine Pegler.

In Memoriam

Thomas B. Brill, Ph.D. (1944-2018)
Photo by Kathy F. Atkinson

JANNAF member, Thomas B. Brill, Ph.D., passed away on July 23, 2018. Described as "a man who believed in being prepared" by the *University of Delaware Daily*, Brill wrote his own obituary below.

Thomas B. Brill, age 74, died of complications from Parkinson's Disease on July 23, 2018.

Born in Chattanooga, Tenn., he grew up in Webster Groves, Mo. His youth was enriched by extensive family camping, travel around the world, schooling in Tasmania, Australia, activity in ham radio, and guiding in the Canadian canoe country.

He received a B.S. degree at the University of Montana, and a Ph.D. from the University of Minnesota in chemistry in 1970. That year he joined the faculty at the University of Delaware and retired in 2006.

He was an experimentalist who thrived on creating new methods to investigate chemistry at elevated temperature and pressure related to explosions, rocket propulsion and deep-sea geothermal vents. He graduated 45 M.S. and Ph.D. students and published more than 300 papers, one book and five co-edited books. He lectured throughout the world and consulted for many years for industry and U.S. national laboratories. For 20 years, he also taught materials properties to art conservation graduate students.

He enjoyed hiking, running, canoeing and mountain climbing. He and his wife won the Gore-Tex triathlon mixed pairs in 1985.

He is survived by his wife, Patricia, of 51 years, daughter Barbara of Rockville, Md., and son Russell and family of Grafing, Germany, with three granddaughters.

JANNAF LPS Advanced Materials Panel Holds TIM

The JANNAF Liquid Propulsion Subcommittee (LPS) Advanced Materials Panel (AMP) held a technical interchange meeting (TIM) in Huntsville, Ala., on Aug. 27-28, 2018. More than 200 attendees participated in the TIM, which included 31 presentations and 30 posters detailing the most advanced technologies in additive manufacturing (AM) for propulsion components. The range of topics discussed included lessons learned and best practices for designing parts for AM, simulation of the AM process to aid in the development and optimization of manufacturing techniques, development of new materials for AM and their mechanical properties, and state-of-the-art techniques and in-situ monitoring of the AM process to detect defects in real time. Much of the TIM was dedicated to two specific topics: evaluating aerospace hardware and components for mechanical properties and hot-fire testing with the goal of achieving flight certification.

Additive manufacturing is being utilized in almost every conceivable propulsion application in an effort to reduce costs by decreasing the amount of hands-on labor necessary for manufacturing complex components, reducing component mass through optimization, and realizing design concepts that until now have not been possible to manufacture using traditional methods. The technology to "3D print" has been around since 1987 with the development of stereolithography for ultraviolet (UV)-cured photoresins. The technology necessary to perform laser sintering (SLS) became available in the early 2000s. However, it was mainly applicable only for special alloys and very small build volumes. SLS has improved tremendously over the past 20 years to the extent that components can now be produced using aerospace materials. Additionally, build volumes have increased to the point where smaller components can be realistically designed to be produced through AM in order to take advantage of the unique capabilities that AM production allows

AM components will become common on spacecraft, space launch vehicles, and propulsion systems as the propulsion community gains a robust understanding of the processes and techniques necessary to ensure that AM components meet, or exceed, the requirements imposed on traditionally manufactured parts. The LPS Advanced Materials Panel and its members are actively working to put standards, procedures, and best practices into place to ensure that AM components become a reliable option when designing for space applications

The presentations from this meeting will be available through the JANNAF Digital Online Collection (JDOC), accessible through the JANNAF website (https://www.jannaf.org/). Please allow 12 weeks for clearances to be reviewed prior to the posting of presentations.

Participants in the LPS additive manufacturing TIM pose in front of a test stand at NASA MSFC used to evaluate AM components.
Photo courtesy of Clyde S. Jones, NASA MSFC.

Participants in the LPS additive manufacturing TIM inspect the additive manufacturing build laboratory at NASA MSFC.
Photo courtesy of Clyde S. Jones, NASA MSFC.

JANNAF to Meet in Vancouver, Washington, for Fall 2018 Meeting

JANNAF members head to the Pacific Northwest for the December 2018 JANNAF Meeting from December 10-13, 2018. The meeting will be held at the Hilton Vancouver Washington hotel in historic downtown Vancouver, Wash., approximately 12 minutes from downtown Portland, Ore., and 20 minutes from the Portland International Airport. The December JANNAF Meeting will feature a joint gathering of the 45th Structures and Mechanical Behavior (SMBS), 41st Propellant and Explosives Development and Characterization (PEDCS), 32nd Rocket Nozzle Technology (RNTS), 30th Safety and Environmental Protection (SEPS) Subcommittees, as well as a meeting of the Programmatic Industrial Base (PIB). The Vancouver meeting will be chaired by J. Robert Esslinger Jr., with the Army Aviation and Missile Research, Development and Engineering Center (AMRDEC).

Robert M. Lightfoot Jr., President of LSINC Corporation, will serve as the keynote speaker on Tuesday, December 11. Lightfoot is the former NASA Acting Administrator. His permanent position at NASA Headquarters was Associate Administrator, the agency's highest-ranking civil service position. He previously was director of the Marshall Space Flight Center in Huntsville, Ala., and spent much of his Marshall career in rocket engine testing and the Space Shuttle propulsion office. Lightfoot also served as director of the Propulsion Test Directorate at NASA Stennis Space Center in Mississippi. After Stennis, Lightfoot spent two years at NASA Headquarters in Washington, D.C., where he focused on strategies for returning the Space Shuttle to flight following the Columbia tragedy. Lightfoot received a bachelor's degree in mechanical engineering from the University of Alabama, where he is currently a Distinguished Departmental Fellow for the Department of Mechanical Engineering, a College of Engineering fellow, and has served on the Mechanical Engineering Advisory Board. He was inducted into the State of Alabama Engineering Hall of Fame in 2010, and has received numerous awards during his NASA career, including the Presidential Rank Award for Distinguished Executives, the highest honors attainable for federal government work, in 2006, 2010 and 2016.

J. Robert Esslinger Jr., AMRDEC, Redstone Arsenal, Ala., will chair the JANNAF meeting in Vancouver, Wash.

Lightfoot's keynote address will focus on the topic of "risk leadership." As new systems and technologies are developed, engineers are challenged to assess the risks associated with fielding something new. This task requires more than "risk management." It requires "risk leadership." Lightfoot's speech will highlight the similarities and differences between approaching engineering challenges from a risk management and risk leadership perspective.

The four technical subcommittees meeting in Vancouver have organized numerous paper sessions, specialist sessions, panels, and workshops that will be of interest to the JANNAF community.

SMBS will address a wide variety of topics, including the development, application, and verification of experimental, analytical, and statistical techniques required in the preliminary or detailed structural design of solid propellant rocket motors and gun ammunition, the assessment of their struc-

tural integrity, and the prediction of their service life based on structural or chemical aging mechanisms.

For those interested in more involvement in the community, SMBS will offer a specialist session on "Non-Destructive Evaluation Needs and Capabilities for Solid Rocket Motors," as well as a "Non-Destructive Evaluation" panel discussion. Representatives from Northrop Grumman Corporation and QuantiTech Incorporated will present a specialist session on "Solid Rocket Motor Lessons Learned." Next, the SMBS will also offer a workshop jointly with RNTS entitled, "Verification, Validation, and Uncertainty Quantification" where participants will work in conjunction with the Modeling and Simulation Subcommittee's Verification, Validation, and Uncertainty Quantification Team to define approaches for these tasks that can be used in the propulsion analytical community with an emphasis on Rocket Nozzle Technology and Structures and Mechanical Behavior.

Robert M. Lightfoot Jr., President of LSINC Corporation, will serve as the keynote speaker on Tuesday, December 11. Lightfoot is the former NASA Acting Administrator. His keynote address will focus on the topic of "risk leadership."

With more than 20 technical sessions and multiple Specialist Sessions, the PEDCS will offer a very full and diverse program on related topics at the December JANNAF Meeting. A specialist session on "CL-20 Efforts - Past, Present, Future Formulations" will summarize and assess past and present efforts to solve the cost issues associated with the production of this propellant and engage in future efforts to promote its development and use. A specialist session entitled, "AOP-7 U.S. National Section Test Methodology Review," will provide a forum for the community to present findings on state-of-the-art test methods for energetic materials characterization and qualification in order to make recommendations to the energetics community (Office of the Secretary of Defense, Departments of Defense and Energy Laboratories, Program Managers, and Industry) for upgrading to the new NATO AOP-7 explosive materials standards. By bringing the developer and user communities together, the goal is to solve these critical technical, financial, and logistical challenges in order to equip our warfighters with state-of-the-art technology.

Other PEDCS program highlights include a two-part specialist session on "Small Scale Sensitivity Testing" and four sessions on the topic of "Propellant and Explosives Process Engineering."

Robert M. Lightfoot Jr. will be keynote speaker at the JANNAF Meeting in Vancouver, Wash.

RNTS will host eighteen papers, one panel, and two workshops in Vancouver. Papers will address various subjects including "Nozzle Thermal, Structural, Fluids Analysis and Modeling;" "Innovative Nozzle Materials; and "Design, Test, Evaluation." "The Nozzle Analysis and Modeling" panel meeting will occur on the afternoon of Tuesday, December 11 and the RNTS Technical Steering Group (TSG) meeting will take place at noon the next day.

In addition to the "Verification, Validation, and Uncertainty Quantification" workshop held jointly with SMBS, RNTS will host a workshop in collaboration with the PIB to assess how well the small-scale testing used to evaluate new rocket motor insulation formulations correlates to sub-scale and full-scale motor testing and to establish best practices for test standardization. This workshop will provide valuable information about the small scale testing current-

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JANNAF Meeting, Vancouver, Washington... *continued from page 7*

ly being performed on replacement insulation candidates and guidance for future test efforts.

SEPS will meet to address issues related to the safety, health and environmental impacts associated with manufacture, storage and use of propellants, explosives and pyrotechnics. Papers, presentation and discussion will address topics such as health effects associated with energetic compounds, precursors, combustion products, and waste products as well as safety concerns present during intentional use, demilitarization, and accidents. New and emerging areas of interest include safety and environmental protection considerations for additive manufacturing of energetic materials, nanomaterials, and insensitive high explosive formulations.

The SEPS will offer a specialist session jointly with PEDCS addressing "Green Energetic Materials," followed immediately by a meeting of the Green Energetic Materials Panel. Other SEPS program highlights include a session on "Demilitarization," a two-part session on "Regulations and New Materials," and a "Toxicology" session on Thursday afternoon.

Lastly, on the morning of Monday, December 10, Stuart Blashill, Energetics Research Group, Columbia, Md., will present a workshop for JANNAF Meeting attendees on the GOTChA (Goals, Objectives, Technical Challenges, and Approaches) project planning process. Attendees may also sign up for one-on-one or small-group sessions with Blashill to discuss the GOTChA process for specific projects. Thirty-minute sessions will be available from Monday afternoon through Thursday afternoon. Please contact Blashill at sblashill@erg.jhu.edu to request a specific day and time.

For complete details on all the papers and topics at the December 2018 JANNAF Meeting, please see the meeting program, which is available through the JANNAF portal at https://www.jannaf.org/mtgs/2018Dec/pages/index.html.

Airbreathing Propulsion Technology Showcases

The Airbreathing Propulsion Subcommittee (APS) has created and made available to JANNAF members several technology showcases. The goal of these showcases is to inform and enlighten the DoD and NASA about airbreathing propulsion technology in a way that allows for understanding of a particular technology topic by technically competent, but not expert, stakeholders in a limited amount of space. These "quick read" articles focus on a variety of timely airbreathing propulsion topics. A review process within the APS has been developed and the webpage for the showcases on the JANNAF website (https://jannaf.org) is accessible to everyone with an active JANNAF Secure Portal account. The technology showcases page may be visited by logging into the JANNAF website, clicking on the Committees tab at the top of the page, selecting the JANNAF Technical link, selecting the APS link on the left-hand side of the page, and then selecting APS Showcases link on the left-hand side of the page (JANNAF Homepage>Committees>JANNAF Technical>APS>APS Showcases).

The following is a list of completed showcases to date:

- "Propulsion Mode Transition," by Charles Trefny, September 16, 2016.
- "Assessing Ramjet Powered Cruise Missile Performance," by John Moore, November 22, 2016.
- "Rotating Detonation Engines," by Thomas Kaemming, January 31, 2017.
- "Endothermic Fuels," by Richard Wills, April 11, 2017.
- "Additive Manufacturing for Airbreathing Propulsion," by Gregory Bruening, April 11, 2017.

For more information, contact the APS Chairman, Mr. Lawrence Huebner, at Lawrence.D.Huebner@nasa.gov.

ERG Staff Engineer Participates in Joint NASA/CTTSO Robotics Competition at NASA Johnson Space Center

A robot travels through a tunnel buried deep underground. Using its camera, it searches every nook and cranny in the dark passageway for potential hazards. It relays this information to its operators in real time, giving them vital information to protect people who will eventually make the same journey.

Although this sounds like a common scenario for the military or border patrol, explains William Bagley, associate research engineer at the Johns Hopkins University's Energetics Research Group, nothing that performs this specialized task currently exists.

That's why Bagley recently participated in a robotics workshop and challenge at NASA's Johnson Space Center in Houston, TX. The event, sponsored by the U.S. Department of Defense Combating Terrorism Technical Support Office (CTTSO), brought together individuals with different backgrounds, including computer programmers, college students, engineers, and bomb technicians.

On a Monday morning in June, the workshop kicked off with an overview of what these participants would be facing for the challenge: They'd work together in teams to design robots capable of passing through a service tunnel on the Johnson Space Center property. To achieve this feat, they'd be given access to various commercial robot kits and accessories and NASA's large vehicle construction building, a machine shop, and workspace with all the manufacturing equipment they'd need.

The tunnel itself presented myriad challenges, Bagley explains. Topping the list was communications: Numerous wires and plumbing lined the twisty tunnel, which lay about 20 feet underground, making radio frequency an unlikely possibility. The tunnel also had physical obstacles, including a set of steep, irregular stairs.

After a brief safety discussion, the participants separated into teams to start building, an iterative process that proceeded over the next four days. On Friday, the teams each lowered their robots into the tunnel to see which one could successfully navigate through while identifying a set of pre-placed hazards. Bagley's team's design—a heavily modified tractor robot—was the only one to meet all the objectives.

"Nothing like this really exists in current fielded systems for military, law enforcement, or the harsh environments of space," Bagley says. "By bringing different minds together, we each played a small role in accomplishing something big."

Article contributed by Christen Brownlee, Johns Hopkins University

William Bagley (left), Energetics Research Group, Columbia, Md., observes a robot during a workshop and competition sponsored by the Department of Defense Combating Terrorism Technical Support Office (CTTSO) at NASA Johnson Space Center, Houston, Texas.

William Bagley (left), Energetics Research Group, Columbia, Md., speaks with a participant in a robotics workshop and competition sponsored by the Department of Defense Combating Terrorism Technical Support Office (CTTSO) at NASA Johnson Space Center, Houston, Texas.

JANNAF Members Gather in Long Beach for May 2018 JANNAF Meeting

JANNAF members met in Long Beach, Calif., in May 2018 for a joint gathering of the 65th JANNAF Propulsion Meeting (JPM) and the 12th Modeling and Simulation (MSS), 10th Liquid Propulsion (LPS), and 9th Spacecraft Propulsion (SPS) Subcommittees, as well as a meeting of the Programmatic Industrial Base (PIB). Major Luke C. Dras, formerly of the Air Force Research Laboratory (AFRL), Edwards AFB, Calif., and now with the Air Force eSchool of Graduate Professional Military Education (PME), Maxwell AFB, Ala., chaired the meeting, which included a keynote address and panels, workshops, and specialist sessions hosted by the subcommittees in attendance.

Roberta Ewart, Chief Scientist, Space and Missile Systems Center (SMC), Air Force Space Command, Los Angeles AFB, Calif., presented a thought-provoking keynote titled "Novel Orbits for Guardians of the High Frontier" that focused methods through which the Air Force could revolutionize how it flies its satellites both in the present and future. Ewart identified three novel orbits that would utilize well-understood orbital mechanics to create new Air Force capabilities. The first, the Parker Transfer Orbit to geosynchronous orbit (GEO), would replace the current Hohmann Transfer Orbit to GEO and use the Sun's gravity to decrease the inclination of a satellite's orbit in order to place it in GEO. The Parker Transfer would require less fuel and reduce a satellite's exposure to the radiation belts surrounding the Earth, thus producing cost savings and potentially extending a satellite's on-orbit lifetime. Adversaries would also have a difficult time tracking satellites after launch. Ewart used a theoretical launch from the Cape Canaveral AFS, Fla., to demonstrate how the Parker Transfer Orbit would work. She noted that the only significant disadvantage of the Parker Transfer Orbit over the Hohmann Transfer Orbit is that the Air Force would have to use NASA's Deep Space Network to communicate with its satellites while they were engaged in the transfer, due to the distance from the Earth. Ewart next discussed a second novel orbit termed a "polesitter" orbit. The polesitter orbit would place a satellite in a perpendicular orbit above the Earth's pole and allow for continuous infrared observation of the GEO orbital plane. She noted that the propulsion and sensor technologies necessary to permit a satellite to sit in a polesitter orbit and observe other satellites in GEO orbit did not yet exist, but development efforts were underway. Cis-lunar orbits were the third type of orbit addressed by Ewart. These types of orbits would place Air Force satellites in the space between the Earth and the Moon and would become increasingly relevant as other nations began to place satellites and spacecraft into cis-lunar orbits. As with polesitter orbits, the Air Force did not currently possess the capability to effectively utilize cis-lunar orbits, but she stated that long-term studies were underway.

Keynote speaker Roberta Ewart, Chief Scientist, Space and Missile Systems Center (SMC), Air Force Space Command, Los Angeles AFB, Calif.

Following Ewart's keynote address, PIB co-chairs Christine Michienzi, Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, the Department of Defense (DoD), Alexandria, Va., and Michael Kynard, Deputy Director of the NASA Michoud As-

sembly Facility, Huntsville, Ala., spoke briefly about the PIB's ongoing activities within JANNAF and discussed some of the PIB-hosted sessions at the Long Beach JANNAF Meeting. Michienzi noted that work was nearing completion on the *Integrated Program Plan and Key Decision Point* report and Kynard highlighted the PIB's commodity panel dealing with standardizing methane acquisition and specialist sessions on test and evaluation (T&E). Kynard also highlighted PIB sponsorship of technical interchange meetings (TIMs) later in the year dealing with additive manufacturing and in-space propulsion (see page 5 for a brief summary of the LPS additive manufacturing TIM).

JANNAF Journal of Propulsion and Energetics Managing Editor Benjamin Schwantes, Ph.D., Energetics Research Group, Columbia, Md., promoted the journal and encouraged attendees to consider submitting papers to the limited-distribution publication. He also highlighted a critical need for reviewers with subject matter expertise in detonation engine technology. Following Schwantes' comments, Mary Gannaway, Energetics Research Group, reminded JANNAF attendees about maintaining custody of their programs and copies of the *JANNAF Journal*, since they were both Distribution C documents.

JANNAF Technical Executive Committee (TEC) NASA representative D.R. Reddy, Ph.D., NASA Glenn Research Center, Cleveland, Ohio (right), presents the JANNAF TEC Lifetime Achievement Award to Unmeel Mehta, Ph.D. (left).

During the awards ceremony, JANNAF Technical Executive Committee (TEC) NASA representative D. R. Reddy, Ph.D., NASA Glenn Research Center, Cleveland, Ohio, presented a JANNAF TEC Lifetime Achievement Award to Unmeel Mehta, Ph.D., NASA Ames Research Center, Calif., for over three decades of leadership and contributions to the JANNAF Airbreathing Propulsion Subcommittee (APS) and the MSS, which he helped to establish in 1999. Mehta's leadership role within the MSS included production of the 2016 *Simulation Credibility Advances in Verification, Validation, and Uncertainty Qualification* report (JANNAF Digital Online Collection (JDOC) 20160-0002). TEC Air Force representative Drew DeGeorge then presented a JANNAF TEC Special Service Award to *JANNAF Journal* Managing Editor Benjamin Schwantes for his work on the publication over the past two years and his efforts to revamp the article submission, review, and publication process. Michael D. Watson, NASA Marshall Space Flight Center, Huntsville, Ala., presented two Best Paper Awards on behalf of the MSS for papers presented at prior MSS meetings. The recipients included Kevin C. Brown, AFRL, Edwards AFB, Calif., for a paper presented during the 2015 Nashville JANNAF Meeting entitled, "Comparison of Steady and Unsteady Simulation of Fuel Film Cooling in Rocket Engines" and Luis M. Bermudez, Ph.D., Northrop Grumman Corporation, Dulles, Va., for a paper presented at the 2016 Phoenix JANNAF Meeting entitled, "Modeling, Simulation and Validation of the Plume Impingement Effects on the Cygnus™ Spacecraft." Lastly, James L. Cannon, NASA Marshall Space Flight Center, Huntsville, Ala., presented a JANNAF Outstanding Achievement Award on behalf of the LPS to teams from three NASA research centers – Glenn Research Center, Cleveland, Ohio, Langley Research Center, Hampton, Va., and Marshall Space Flight Center, Huntsville, Ala. – for their work on the "Low

JANNAF Technical Executive Committee (TEC) Air Force representative Drew DeGeorge (right) presents a JANNAF TEC Special Service Award to* JANNAF Journal *Managing Editor Benjamin Schwantes, Ph.D. (left).

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Cost, Upper Stage-Class Propulsion Element" project, which utilized additive manufacturing practices to produce a combustion chamber comparable to current standards for less cost and more rapidly than us-

James L. Cannon, NASA Marshall Space Flight Center, Huntsville, Ala. (right), presents a JANNAF Outstanding Achievement Award to Christopher S. Protz, Ph.D., NASA Marshall Space Flight Center, Huntsville, Ala. (left), for work on the "Low Cost, Upper Stage-Class Propulsion Element" project. Protz accepted the award on behalf of research teams from three NASA research centers– Glenn Research Center, Cleveland, Ohio, Langley Research Center, Hampton, Va., and Marshall Space Flight Center, Huntsville, Ala.

ing traditional manufacturing techniques. Christopher S. Protz, Ph.D., NASA Marshall Space Flight Center, Huntsville, Ala., accepted the award on behalf of the NASA research teams.

The three JANNAF Technical Subcommittees that met in Long Beach held many interesting and informative panels, workshops, and specialist sessions during the four-day meeting. MSS hosted sessions on various topics including modeling for the Europa Clipper space mission, slosh modeling, uncertainty quantification, verification, and validation of multiple applications, as well as integrated health management of systems using sensors. There were promising advances in each of the MSS mission areas. Some key highlights include: quantification of how beneficial model-based system engineering is for the Europa Clipper mission; a discussion about a number of improvements in anti-slosh baffle design and modeling, and how the improvements will be used by industry; and the presentation of an in-site sensor to measure and model metal erosion in combustion chambers, which could have far reaching applications in reusable rocket engines.

A well-attended specialist session and demonstration was held on modeling tools, including FEM (Finite Element Method) Builder, HERO (Heat Transfer and Erosion Analysis Program), and ROCETS (Rocket Engine Transient Simulation). Audience members found the demonstration extremely useful and expressed interest in continuing the practice at future meetings and recording future demonstrations for publication on JDOC in order to provide a reference source for the MSS community.

A workshop on uncertainty quantification was held, which focused on examples of how to complete an uncertainty quantification analysis specifically using the P-box method. This is one in a series of workshops aimed at developing a guide that explains this method through examples. At the first workshop, held at Orbital ATK's (now Northrop Grumman Innovations Systems') facility in Ogden, Utah, in September 2017 (JDOC 2017-0011), the participants expressed a desire to develop examples of uncertainty quantification for the MSS community. These examples would complement the more encompassing model uncertainty quantification, verification, and validation work that was published in 2016 (JDOC 2016-0002). The aim of an example-driven document is to provide a reference source with examples that younger engineers and others unfamiliar with uncertainty quantification can utilize in order to develop a deeper understanding of the subject. The examples being developed are multidisciplinary and intended to be relevant for as broad an audience as possible.

Unmeel Mehta, Ph.D., NASA Ames Research Center, Calif., stepped down from the MSS Technical Steering Group (TSG) after 18 years as a member. Mehta was instrumental in establishing the MSS subcommittee, served for a time as its chair, and provided invaluable expertise and direction to the subcommittee during his long tenure. As previously noted, JANNAF TEC honored Mehta for his leadership and support of the MSS with the JANNAF TEC Lifetime Achievement award.

Robert A. Baurle, Ph.D., NASA Langley Research Center, Va., was voted in as Mehta's replacement as NASA representative on the TSG.

LPS hosted more than 89 presentations, which were spread across 20 technical sessions and covered a range of topics currently affecting liquid propulsion research. Highlights include the well-attended plenary session "U.S. Government's Role in Future Liquid Rocket Engine Development and Technology Maturation." Moderated by Wayne Hale, Director of Human Spaceflight and Energy Services for Special Aerospace Services, LLC, Boulder, Colo., and the former NASA Space Shuttle Program Manager, the plenary panel discussed how to the U.S. government can best accelerate new liquid rocket engine (LRE) technology and effectively partner with private aerospace companies to do so. The panel's lively discussion incorporated a wide range of views from both government and industry participants, including those of Tim Ellis, Relativity Space, Los Angeles, Calif., Curtis W. Johnson, Blue Origin, Kent, Wash., Scott Macklin, Virgin Orbit, Long Beach, Calif., Shawn H. Phillips, AFRL, Edwards AFB, Calif., William F. Sack, Aerojet Rocketdyne, Canoga Park, Calif., Michael Sanjume, Air Force Space and Missile Systems Center (SMC), Los Angeles AFB, Calif., Jeffrey A. Sheehy, NASA Headquarters, Washington, D.C., and Jeffery T. Thornburg, Stratolaunch, Huntsville, Ala.

LPS technical presentations addressed new research in a wide range of topics as well, with traditional subjects such as combustion stability, hydrocarbon fuels, and turbomachinery; and newer topics such as additive manufacturing, methane characterization, and modular rocket engines being covered as well. Highlights in the field of combustion stability included a technical session on "Combustion Stability Tool Development (CSTD) Results," as well as a session detailing the revision efforts on CPIA Publication 655, *Guidelines for Combustion Stability Specifications and Verification Procedures from Liquid Propellant Rocket Engines*. Green propellants featured prominently in other sessions, with the Green Propellant Infusion Mission expected to launch by the end of 2018. Progress and results from the Hydrocarbon Boost Program at AFRL were featured heavily in a number of sessions. In a dedicated outreach effort, a special session dedicated to rocketry projects by local university students was spearheaded by Nils Sedano, AFRL, Edwards AFB, Calif., and gave students a chance to network with aerospace technical leads from the government and industry. The use of methane in LOX/LCH4 engines and development efforts to support this new design fea-

Keynote speaker Roberta Ewart, Chief Scientist, Space and Missile Systems Center (SMC), Air Force Space Command, Los Angeles AFB, Calif. (left) and JANNAF Meeting Chair Major Luke C. Dras, Air Force eSchool of Graduate Professional Military Education, Maxwell AFB, Ala. (right).

tured prominently in LPS sessions as well. Sessions dealing with new studies of the characterization and use of additive manufacturing in liquid rocket engines were also well attended.

SPS hosted two workshops and 10 sessions on spacecraft chemical propulsion, electric propulsion, and micro propulsion, with a total of 43 papers and three invited presentations. Paper session topics included advanced propulsion concepts, bipropellants, materials and components, programs and systems, test results, electric propulsion flight data and mission concepts, hall thruster research and development, micropropulsion in-space propulsion systems, and micropropulsion electrosprays.

The three SPS Panels met to discuss ongoing and new activities. The Micro-Thrust Propulsion Panel held its meeting on the specific topic of "SmallSat Propulsion Technology Readiness Level Standard Definition." Participants discussed whether the need exists for a JANNAF Guideline or Standard, concluding that a guideline would be best. The co-chairs solicited feedback from the community on

(continued on page 16)

JANNAF May 2018 Meeting... *continued from page 13*

a peer-reviewed *JANNAF Journal* article on the subject. After the JANNAF Meeting, representatives from key organizations began the process of receiving feedback and reconciling the differences between the various organizations in order to create a JANNAF Guideline.

The Chemical Propulsion Panel held a panel meeting on "Development Needs in Modern Chemical Spacecraft Propulsion Systems." Discussion topics included system and propellant contamination, delivered performance including optimization and robustness for meeting increasing demands for end of life operations, thrust scaling, state of the art systems, material obsolesce and new replacement materials, vender supply and material processing changes, green propellant toxicity and hazard classifications, and material compatibility. Future JANNAF TIMs will allow the industry to share its concerns on these topics.

The Electric Propulsion Panel held a normal summary meeting of their numerous ongoing activities, and an "Electric Propulsion Operation in the Space Environment and Facility Interactions III (EPOSE - III)" workshop. Workshop participants heard presentations and discussed recent work involving electric propulsion measurement results from modeling and simulation, ground test results, diagnostics and sensor packages integration, and on-orbit environmental data and flight results.

In all, JANNAF participants expressed satisfaction with the meeting and felt that the various sessions proved useful for themselves and their organizations.

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A complimentary JANNAF Secure Portal account is your gateway to the CPIN suite of JANNAF Databases. Through this secure online portal, you will also have access to JANNAF meeting registration information and online meeting programs, JANNAF collaborative workspaces, and more than 25,000 unclassified JANNAF and ERG legacy publications. The ERG can also facilitate the purchase of computer codes, additional TBI services, and classified ERG or JANNAF publications.

With the JANNAF portal, members can easily share sensitive documents with team members on the secure online platform through the small teams collaborative sites. Folder permissions can be set to restrict access to only those with a need to know.

The JHU WSE Energetics Research Group (ERG) offers both unclassified and classified-level technical products and services by subscription. Non-government subscribers to ERG products and services are required to maintain active registration with the Defense Logistics Agency (DLA) to receive export-controlled, militarily critical technical information. They must also be certified by a sponsoring government official to document that they are currently performing work under a government contract. Classified-level subscribers must also possess a classified contract in the propulsion technology area.

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For further information about ERG products and services and related charges, please visit https://www.erg.jhu.edu/subscriptions or contact the ERG Customer Service Line at (410) 992-7300 or Tricia Reider at treider@erg.jhu.edu.

***JANNAF News* is seeking short (Dist A) technical articles for future editions.**
If you are interested in submitting an article or have any questions, please contact Managing Editor Benjamin Schwantes at bschwantes@erg.jhu.edu

ERG's IT Team Serves JANNAF Members at Meetings and Online

The Energetic Research Group's (ERG's) Information Technology (IT) team serves the ERG staff at Johns Hopkins University, as well as members of the JANNAF community, by providing IT resources for all of their networking needs. This team, led by Bruce Dennett, manages all aspects of the IT requirements at the JANNAF meetings, along with the JANNAF website (https://www.jannaf.org), which houses the JANNAF Secure Portal and all of its tools to make networking across organizations and geographical locations easier. Dennett manages department operations, and oversees the IT infrastructure for both ERG and JANNAF, particularly the firewall and Internet connections.

The IT team also has two other members — Valerie Dixon and Paco Wong. Dixon maintains the ERG office servers, and all of ERG's equipment. She also sets up and manages the Wi-Fi infrastructure at JANNAF meetings. Wong is the webmaster and principle programmer for applications on the JANNAF website and the Portal. If you have questions about your JANNAF Portal or need help with the Small Teams sites, any of the IT staff can assist you by phone prior to the meeting. At the meeting, you will see Bruce, Valerie, and Paco in the meeting rooms loading presentations onto laptops, as well as in the IT Room collecting presentations throughout the week. The IT Room for the December 2018 JANNAF Meeting will be located in the Alder Room, adjacent to the registration desk at the Hilton Vancouver Washington hotel.

Bruce Dennett

Valerie Dixon

Paco Wong

The *JANNAF Journal of Propulsion and Energetics* is seeking reviewers and associate editors 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

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

PEDCS Meets at ERG Conference Facility for Workshop on Additive Manufacturing of Energetic Systems

Members of the JANNAF Propellant and Explosives Development and Characterization Subcommittee (PEDCS) met at the Johns Hopkins University, Whiting School of Engineering, Energetics Research Group's (ERG's) conference facility in Columbia, Md., in April 2018 for a workshop on additive manufacturing (AM) of energetic systems. The workshop was the first limited-access meeting on the additive manufacturing of energetics held by JANNAF. The meeting included 28 presentations by the seven organizations present (Army, Navy, Air Force, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratories, and the Department of Energy), as well as an open forum at the end of the workshop for participants to discuss future meeting, security concerns, and other matters. PEDCS members felt strongly that future limited-access workshops on additive manufacturing of energetics should be held in conjunction with regularly scheduled JANNAF Meetings.

JANNAF subcommittees are entitled to free use the ERG's 1,200-square-foot conference facility in Columbia, Md., for meetings, including those at the restricted or classified level. The facility can accommodate up to 60 attendees. For more information, please contact Debbie Eggleston at dse@jhu.edu.

Participants in Networking Night at the May 2018 JANNAF Meeting in Long Beach, Calif.

Participants in Networking Night at the May 2018 JANNAF Meeting in Long Beach, Calif.

66th JPM / PIB / 49th CS / 37th APS / 37th EPSS / 31st PSHS
June 3-7, 2019
Dayton, Ohio

Questions

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

JANNAF Liquid Fuels Database Updated

The Liquid Propulsion Fuels Database (LPFD) has been updated with material compatibility data for the green monopropellant AF-M315E. Over the last few years, there have been significant developments in green monopropellants to replace hydrazine. Material compatibility has been a major focus of research and development efforts. Over 29 metals and 12 nonmetals have been studied under various conditions. Coatings, anodization, and physical defects have also been examined. All of the current data regarding AF-M315E has been compiled into the LPFD with short test explanations, as well as references for the cited literature. The LPFD is accessible through the JANNAF website (https://www.jannaf.org/).

Why Should You Attend a JANNAF Meeting?

The most recent JANNAF meeting, held in Long Beach, Calif., in May 2018, was the most well attended meeting in recent years. There were 384 attendees, with 153 from government organizations including NASA, the U.S. Army, the U.S. Air Force, and the U.S. Navy; 203 attendees from industry; and 28 from academia.

Evaluation results from the recent meeting revealed that quality of technical content, networking opportunities and the ability to discuss ITAR information with peers, were the most valuable aspects of the meeting.

Below, please see a sampling of some of the anonymous comments found in the evaluation results regarding the aspects attendees found most valuable about JANNAF meetings:

"It is the best meeting of the year for engineering as the technical papers and class of audience is far superior to other meetings."

"The JANNAF meeting helps my company stay informed on current trends and the state of the art in rocket technologies."

"I use the JANNAF meetings to foster collaborations with others working in the field. I enjoy seeing new people come to the meetings so we can get new thinking into problems we have and also get our work out to those who are working in the green propulsion field."

"It has had a significant impact in that it provides the opportunity to interact with individuals who do similar research. This research community is small so it's important to have a venue that everyone can convene at, present their work, and receive critical feedback."

"JANNAF provides an excellent resource to assist in focusing our work more effectively and learning lessons from industry as opposed to making expensive mistakes ourselves."

Many people also noted that JANNAF provides the only venue for publishing ITAR material, especially research for the hypersonics community.

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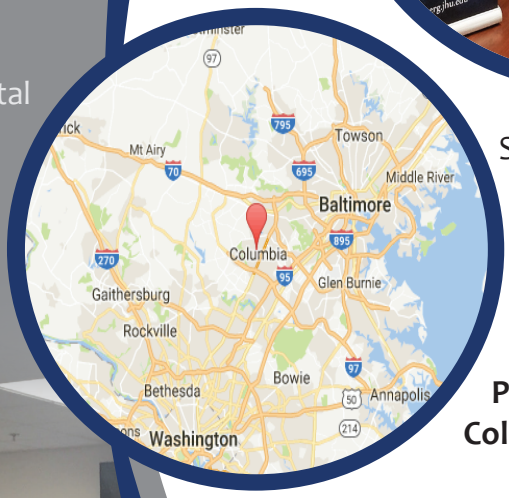

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