FALL 2019

JANNAF NEWS

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

Volume 8, Issue 2 Released October 14, 2019 / Revised November 7, 2019

JANNAF Meeting Features a Return to the Moon, *JANNAF Journal's* 10th Volume

As the country celebrated the 50th anniversary of the Apollo 11 mission earlier this year, NASA has been making big plans for returning humans to the moon, which will be discussed during the keynote speech at the JANNAF meeting in Tampa, Fla., Dec. 9-13. The featured speaker at the December meeting is Marshall Smith, Director of Human Lunar Exploration Program at NASA Headquarters. The upcoming meeting will take place at the Hilton Tampa Downtown and all sessions will be held on site. It will feature a joint gathering of the 13th Modeling & Simulation (MSS), 11th Liquid Propulsion (LPS), and 10th Spacecraft Propulsion (SPS) Subcommittees, as well as a meeting of the Programmatic and Industrial Base (PIB). The Tampa meeting will be chaired by Hani Kamhawi, Ph.D., with NASA Glenn Research Center.

Hani Kamhawi, Ph.D., NASA Glenn Research Center, Cleveland, Ohio, will chair the JANNAF Meeting in Tampa, Fla.

Marshall Smith's keynote speech will be held on Tuesday, Dec. 10. The speech, "Moon to Mars: How NASA will Return Humans to the Moon, with Sights Set on Mars," will focus on the future of human spaceflight. NASA has accepted a bold challenge to send the first woman and next man to the lunar South Pole by 2024. Together with U.S. industry and international partners, the agency is accelerating its work to establish the core lunar infrastructure needed by 2024, with a focus on vehicle and systems options that will support future human missions to Mars.

(See Tampa, Fla., on page 3)

Editor: Benjamin S.M. 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.

ERG is the technical support contractor for the JANNAF Interagency Propulsion Committee operated by the Johns Hopkins University Whiting School of Engineering under contract FA9300-19-C-0002.

Recent ERG Publications

PROCEEDINGS

- Abstract Number: 2019-001
  Meeting Proceedings of the 66th JANNAF Propulsion Meeting / Programmatic and Industrial Base / 49th CS, 37th EPSS, and 31st PSHS Joint Subcommittee Meeting (Dayton, Ohio.)
  Jun 2019
- All meeting proceedings are available in the JANNAF Digital Online Collection (JDOC) database, accessible through the JANNAF website (https//www.jannaf.org/).

ERG's Technical/Bibliographic Inquiry Service

ERG offers a variety of services to its subscribers, including responses to technical/bibliographic inquiries. Answers are usually provided within three working days, in the form of telephoned, faxed, electronic, or written technical summaries. Customers are provided with copies of JANNAF papers, excerpts from technical reports, bibliographies of pertinent literature, names of recognized experts, propellant/ingredient data sheets, computer programs, and/or theoretical performance calculations. The ERG staff responds to numerous inquiries each year, from over 150 customer organizations. For further information, please contact David Owen by email at dowen@erg.jhu.edu.

ERG Subscriptions

ERG forwarded GFY 2019 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 yearly 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 a yearly 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 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

Tampa, Fla.... *continued from page 1*

Smith has been with NASA for more than 30 years. He previously served as the Director of Cross-program System Integration for the Exploration Systems Development Division at NASA Headquarters. He was responsible for Systems Engineering and Integration (SE&I) for NASA's Orion crew vehicle, Space Launch System (SLS) heavy-lift vehicle, and supporting ground systems and operations. He also served as SE&I lead for the Lunar Gateway, a spacecraft that will orbit around the Moon and provide living and research facilities for astronauts, as well as greater access to the lunar surface. Prior to his SE&I work, Smith served as NASA Langley Research Center lead for Ares activities, Flight Test 2 Manager for the Constellation Program, Ares I-X SE&I Chief, and participated on the SLS formulation team. He has also done work in flight simulation, aircraft, robotic, and human spaceflight systems for NASA during his career. Smith received his Master of Science in electrical and computer engineering from Virginia Polytechnic Institute and State University and a Bachelor of Science in electrical and computer engineering from the University of Tennessee. He is the recipient of the NASA Systems Engineering Excellence of the Year Award and the NASA Outstanding Leadership Medal.

Marshall Smith's keynote speech will be held on Tuesday, Dec. 10. The speech, "Moon to Mars: How NASA will Return Humans to the Moon, with Sights Set on Mars," will focus on the future of human spaceflight.

There will also be an opportunity to celebrate the *JANNAF Journal of Propulsion and Energetics* at the December meeting. *JANNAF Journal* staff will be distributing the publication's 10th volume at the Tampa JANNAF Meeting, with a special reception to observe this milestone on Tuesday, Dec. 10, from 3:05-4:05 p.m. in the Networking Room. All past and current authors, associate editors, and reviewers are encouraged to attend. Cake and ice cream will be served.

For complete details on all the papers and topics at the December 2019 JANNAF Meeting, please see the meeting program, which is available through the JANNAF portal at https://www.jannaf.org/mtgs/2019Dec/pages/index.

Marshall Smith, Director, Human Lunar Exploration Program, NASA Headquarters, Washington, D.C., will be the keynote speaker at the JANNAF Meeting in Tampa, Fla.

Come Celebrate the Publication of the *JANNAF Journal's* 10th Volume at the Tampa JANNAF Meeting!

In honor of our 10th volume, please join the *JANNAF Journal* staff for ice cream and cake in the Networking Room (Bayshore I in the Hilton Tampa Downtown) on Tuesday, December 10 from 3:05-4:05 p.m. during the day's afternoon break. All past and current authors, associate editors, and reviewers are encouraged to attend.

Tampa Meeting Subcommittee and Working Group Highlights

MSS

The JANNAF 13th Modeling and Simulation Subcommittee meeting will have sessions on the following topics:

- Rotating detonation engine (RDE) modeling (including a panel meeting)
- Statistical modeling
- Launch vehicles
- Aging surveillance and predictive modeling
- Two code demonstrations, GFSSP (Generalized Fluid System Simulation Program) and ROCETS (Rocket Engine Transient Simulation), plus a meeting for current ROCETS users
- Simulation credibility, surrogate modeling, and uncertainty quantification (including a panel meeting)
- Nonlinear slosh damping
- Solid propulsion and insensitive munitions modeling
- Aerospike engine analysis
- System autonomy (including a panel meeting)
- Interplanetary propulsion

The strong focus on RDE modeling is necessary for establishing baseline capabilities of current RDE technology. Currently, an ideal RDE model does not exist, and there is debate within the community about what such a model should look like. Propulsion system modeling will be discussed extensively at the meeting in order to establish synergies with the LPS and SPS groups in attendance. Most forms of propulsion modeling will be covered, including specialist sessions on nonlinear slosh damping modeling for tank design, aging surveillance and predictive modeling of solid rocket motors, and statistical modeling. Traditionally, code demonstrations are among the most popular MSS sessions. At this meeting, there will be two sessions covering GFSSP and ROCETS. The ROCETS demonstration will include a user group discussion.

The MSS will also host regular paper sessions. The Modeling and Simulation of System Autonomy, Simulation Credibility, and Model Based Systems Engineering panels will each meet. These panel meetings will address progress and improvements in the areas of simulation techniques, model development, predictive aging, system autonomy, and verification, validation, and uncertainty quantification for simulations.

LPS

The JANNAF 11th Liquid Propulsion Subcommittee meeting will cover a wide variety of topics including liquid rocket engine system analysis, combustion subsystems and components, and propellant feed and pressurization systems, along with advanced materials for all of these applications. Within these overarching topics, specific paper sessions at the meeting will cover topics such as combustion stability and dynamics, modelling and best practices for propellant tank feed and pressurization systems, additive manufacturing component development and testing, oxygen-rich combustion developments, turbomachinery developments, linear and rotating detonation engines, and the characterization of hydrocarbon fuels. Other specific topics include testing and analysis of liquid methane and aerospike engines.

For those wishing to be more involved with the LPS community, panel meetings offer a chance to participate in discussions of specific topics. The following panels will have meetings to discuss current tasks and progress: Combustion Stability, Advanced Materials, Hydrocarbon Fuels, and Turbomachinery. Also of note will be a specialist plenary session, "U.S. Small Launch Industry Perspectives on Future Liquid Rocket Engine (LRE) Development," featuring speakers from different commercial launch providers.

SPS

The JANNAF 10th Spacecraft Propulsion Subcommittee has organized nine technical sessions in the area of chemical propulsion, electric propulsion, micropropulsion, and advanced propulsion. A total of 58 papers will be presented. A specialist session entitled, "Recent Developments in Nuclear Propulsion," will be held on Wednesday morning and the panel will include

eight panelists from NASA, the Department of Defense (DoD), industry, and academia. A two-part workshop on Electric Propulsion Operation in the Space Environment and Facility Interactions IV (EPOSE IV) will be held on Wednesday afternoon and Thursday morning, respectively. The EPOSE workshop will continue to address topics related to improving the community's understanding on differences between electric propulsion device performance and stability during ground tests and in-Space operation. Experts from NASA, DoD, industry, and academia will present on recent in-flight data, upcoming flight opportunities, flight plasma diagnostics package developments, ground facility experiments, and advancements in numerical modeling.

PIB

The JANNAF Programmatic and Industrial Base Working Groups will be meeting to develop the PIB's bi-annual Integrated Program Plan and Key Decision Points (IPP/KDP) Report, which will be delivered to senior DoD and NASA leadership in 2020. The IPP/KDP report is an important government program analysis that focuses on areas of common concern and issues within government rocket propulsion programs. In addition, the JANNAF-PIB Co-Chairs will continue their dialogue with this meeting's Technical Subcommittee Chairs, seeking ways to benefit from information exchange and ways to collaborate.

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

JANNAF Secure Portal and JDOC FAQ

What does my JANNAF Secure Portal offer me?

- With your active JANNAF Secure Portal account, you have access to the JANNAF Digital Online Collection (JDOC) containing 26,000-plus papers, presentations, reports, standards, and manuals available in their entirety in downloadable PDF format.

Can anyone access JDOC?

- All government employees receive JDOC at no cost with their Secure Portal account. Government contractors must either have attended and paid the full registration fee for a recent JANNAF Meeting or have paid an annual subscription fee for JDOC access.

Where can I find information on subscriptions?

- Subscription information may be found at https://www.erg.jhu.edu/subscriptions or by contracting Tricia Reider at treider@erg.jhu.edu.

Are all papers in JDOC available to download?

- You will find metadata only for classified papers and unclassified papers with distribution statements other than U-A (approved for public release) or U-C (Distribution to U.S. Government Agencies and their Contractors). Please contact ERG directly to request a copy of these papers.

How do I access JDOC and/or create a Secure Portal account?

- To access the JDOC database, simply go to www.jannaf.org and log into your Secure Portal account. If you do not have a Portal account, please click on the "Create new account" link below the login section on the JANNAF website.

How can I search for papers or proceedings in JDOC?

- You can search for papers, proceedings, and reports using the title, author, or abstract number of the publication. If you have attended a recent JANNAF Meeting, you can locate the abstract numbers for any of the papers presented at that meeting in the back of the JANNAF Meeting program.

JANNAF Attendees Gather in Dayton, Ohio, for June 2019 JANNAF Meeting

Keynote speaker Mark Lewis, Director, Institute for Defense Analyses' Science and Technology Policy Institute, in Dayton, Ohio.

JANNAF attendees met in Dayton, Ohio, in June 2019 for a joint gathering of the 49th Combustion Subcommittee (CS), 37th Airbreathing Propulsion Subcommittee (APS), 37th Exhaust Plume and Signatures Subcommittee (EPSS), and 31st Propulsion Systems Hazards Subcommittee (PSHS), as well as the 66th JANNAF Propulsion Meeting (JPM) and Programmatic and Industrial Base (PIB) Meeting with some joint sessions cohosted by the Modeling & Simulation Subcommittee (MSS). David Gonzalez, Ph.D., Naval Surface Warfare Center, Indian Head Explosive Ordnance Disposal Technology Division (NSWC-IHEODTD), chaired the meeting.

Mark Lewis, Ph.D., Director of the IDA (Institute for Defense Analyses') STPI (Science and Technology Policy Institute) in Dayton, Ohio, served as the keynote speaker for the meeting. Lewis' keynote speech, "Towards a Coherent National Strategy in Hypersonics," addressed the importance of hypersonics research and development for the United States and argued that the United States was at a pivotal moment in the development of hypersonic (i.e., Mach 5+) vehicles and weapons systems. Lewis began his presentation by observing that the final episode of the original Star Trek series had aired almost exactly 50 years prior to the JANNAF Meeting. An important, and in many respects unremarkable, aspect of the show, Lewis noted, was the presence of single-stage-to-orbit shuttlecraft that routinely transported crew from orbit to the ground and back. He argued that hypersonic airbreathing propulsion systems represented the best contemporary technical means for achieving the goal of routine, single-stage-to-orbit spaceflight. However, Lewis argued, another key use of hypersonic propulsion, both airbreathing and rocket powered, was in the development of new weapons systems. It was essential that the United States field such systems in the near future, as well as prepare to defend its assets against hypersonic weapons deployed by potential adversaries such as Russia and China. Lewis reviewed the various rocket-powered American hypersonic weapons projects currently on the drawing board, such as the Prompt Global Strike Program's Advanced Hypersonic Weapon and the Defense Advanced Research Projects Agency (DARPA)-supported Falcon Hypersonic Test Vehicle, as well as airbreathing hypersonic propulsion projects. Ultimately, Lewis argued, despite current Department of Defense (DoD) and DARPA efforts to develop hypersonic weapons and prioritization of hypersonic research, the United States had allowed its lead in the field to slip by cancelling successful hypersonic propulsion research programs such as the National Aeronautics and Space Administration's (NASA's) X-43 project and the Air Force's X-51 flight test vehicle. Similarly, failure to fund ground-test facilities such as NASA and Air Force operated supersonic wind tunnels had led to a shortage of such test facilities. Lewis also expressed concern that the United States was not providing sufficient support for fundamental, university-based research on hypersonics, particularly compared with nations like China. He hoped that a new coherent

Timothy Lawrence (center), NASA Marshall Space Flight Center (MSFC), Huntsville, Ala., accepts the Dr. Kendall K. Brown Award from Programmatic and Industrial Base Executive Committee Co-chairs Christine Michienzi (right), Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, Department of Defense, Alexandria, Va., and Robert Champion (left), NASA MSFC, Huntsville, Ala., on behalf of the late Alex Priskos, NASA MSFC, Huntsville, Ala.

national offensive and defensive strategy for developing the next generation of hypersonic technologies (for both tactical and long-range applications) and cultivating the next generation of hypersonic researchers based on cooperation between the DoD and NASA, with firm leadership at the national level, would enable the United States to reestablish itself as a world leader in the hypersonics field.

An awards ceremony followed the keynote address. Christine Michienzi, Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, at DoD, and Robert Champion, NASA Marshall Space Flight Center (MSFC), both members of the PIB Executive Committee (PEC) presented the PEC's Dr. Kendall K. Brown Award posthumously to Alex Priskos, NASA MSFC for his contributions to the PIB's Large Solid Propulsion Working Group and the PEC, as well as his broader programmatic contributions to NASA and the DoD. The award was accepted by Timothy Lawrence NASA MSFC, who praised Priskos as a larger-than-life strategic thinker with a "vision of the future, [who] provided tremendous leadership [to the propulsion community]."

Homayun Navaz, Ph.D., Software and Engineering Associates, Inc., Carson City, Nev., accepts a Technical Executive Committee Lifetime Achievement Award from Rose Pesce-Rodriguez, Ph.D., CCDC Army Research Laboratory, Aberdeen Proving Ground, Md., on behalf of Douglas Coats, Software and Engineering Associates, Inc., Carson City, Nev.

Robert Mercier, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio, accepts the JANNAF Technical Executive Committee (TEC) Leadership and Service Award from Rose Pesce-Rodriguez, Ph.D., CCDC Army Research Laboratory, Aberdeen Proving Ground, Md., for his service as the TEC liaison to the JANNAF Journal of Propulsion and Energetics

Next, Rose Pesce-Rodriguez, Ph.D., with CCDC Army Research Laboratory located at Aberdeen Proving Ground, Md., presented the JANNAF Technical Executive Committee (TEC) Leadership and Service Award to Robert Mercier, Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base (AFB) in Ohio, for his valuable service as the TEC liaison to the *JANNAF Journal of Propulsion and Energetics*. Pesce-Rodriguez also presented a TEC Lifetime Achievement Award to Douglas Coats, Software and Engineering Associates, Inc., located in Carson City, Nev., for his contributions to the Exhaust Plume & Signatures Subcommittee (EPSS) and the JANNAF community through his development of

(See June 2019 JANNAF Meeting on page 8

June 2019 JANNAF Meeting... *continued from page 7*

the Solid Performance Program (SPP) code. Homayun Navaz, Ph.D., also from Software and Engineering Associates, Inc., accepted the award on Coats' behalf.

Airbreathing Propulsion Subcommittee (APS) Chair Lawrence Huebner (center), NASA Marshall Space Flight Center, Huntsville, Ala., presents the APS Best Paper Award from the December 2017 JANNAF Meeting to Daniel Cuppoletti (not pictured), Ph.D., National Academy of Sciences, Dayton, Ohio, Timothy Ombrello (right), Ph.D., Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio, and Keith Rein (left), Ph.D., Spectral Energies, LLC, Bevercreek, Ohio.

Airbreathing Propulsion Subcommittee (APS) Chair Lawrence Huebner, NASA MSFC, then presented the APS Best Paper Award to Daniel Cuppoletti, Ph.D., National Academy of Sciences, in Dayton, Ohio; Timothy Ombrello, Ph.D., AFRL, Wright-Patterson AFB; and Keith Rein, Ph.D., Spectral Energies, LLC, of Bevercreek, Ohio, for their December 2017 JANNAF Meeting paper entitled, "Pulse Detonation Development and Maturation for Scramjet Combustors." Huebner also presented an APS Best Paper Award to Robert Baurle, Ph.D., of NASA Langley Research Center in Hampton Va., and Eric L. Axdahl, Ph.D., of The Spaceship Company, located in Mojave, Calif., for the December 2017 JANNAF Meeting paper entitled, "Uncertainty Quantification of CFD Data Generated for a Model Scramjet Isolator Flowfield." Following the Best Paper Awards, Huebner presented two APS Lifetime Achievement Awards. The first was awarded posthumously to Herbert Lander Jr. for his broad and in-depth work on hydrocarbon fuel chemistry for hypersonic flight. The award was accepted by Donald Phelps, Ph.D., of AFRL, Wright-Patterson AFB. The second award went to Thomas Jackson, Ph.D., AFRL (retired), Wright-Patterson AFB, for his scientific and engineering work in hypersonic flight and leadership in airbreathing hypersonic propulsion development programs at the DoD and NASA, as well as his support of the APS at JANNAF.

Donald Phelps (left), Ph.D., Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio, accepts an Airbreathing Propulsion Subcommittee (APS) Lifetime Achievement Award from APS Chair Lawrence Huebner (right), NASA Marshall Space Flight Center, Huntsville, Ala., on behalf of the late Herbert Lander Jr.

Thomas Jackson (left), Ph.D., Air Force Research Laboratory (retired), Wright-Patterson Air Force Base, Ohio, accepts an Airbreathing Propulsion Subcommittee (APS) Lifetime Achievement Award from APS Chair Lawrence Huebner (right), NASA Marshall Space Flight Center, Huntsville, Ala.

Following Huebner's presentation, EPSS Technical Steering Group (TSG) Chair Milton "Ed" Vaughn,

Ph.D., CCDC Aviation & Missile Center located at Redstone Arsenal, Ala., presented an EPSS Lifetime Achievement Award to John Conant, Aerodyne Research, Inc., of Billerica, Mass., for his service to the

Robin Miller, Naval Air Warfare Center Weapons Division, Point Mugu, Calif., accepts an Exhaust Plume and Signatures Subcommittee (EPSS) Lifetime Achievement Award from EPSS Technical Steering Group (TSG) Chair Milton "Ed" Vaughn, Ph.D., CCDC Aviation & Missile Center, Redstone Arsenal, Ala., on behalf of John Conant, Aerodyne Research, Inc., Billerica, Mass.

JANNAF community in the development of the Spectral and In-band Radiometric Imaging of Targets and Scenes (SPIRITS) missile, aircraft, and hardbody signature plume code. The award was accepted on Conant's behalf by Robin Miller, Naval Air Warfare Center Weapons Division, Point Mugu, Calif. Lastly,

Milton "Ed" Vaughn, Ph.D., CCDC Aviation & Missile Center, Redstone Arsenal, Ala., accepts a Propulsion Systems Hazards Subcommittee (PSHS) Special Recognition Award from PSHS Technical Steering Group Chair Adam Brand, Air Force Research Laboratory, Edwards Air Force Base, Calif., on behalf of Jamie Fisher, CCDC Aviation & Missile Center (retired), Redstone Arsenal, Ala.

Propulsion Systems Hazards Subcommittee (PSHS) TSG Chair Adam Brand, AFRL, Edwards AFB, Calif., presented the PSHS Best Paper Award to Benjamin Wilde, Ph.D., AFRL, Eglin AFB, Fla., Eric Welle, Ph.D., AFRL at Eglin AFB, Fla., and Chad Rumchik, AFRL at Eglin AFB, Fla., for their December 2017 JANNAF Meeting paper entitled, "Wedge Test Results and Analysis for PBXN-5." Brand closed the awards

Keynote speaker Mark Lewis, Director, Institute for Defense Analyses' Science and Technology Policy Institute, Dayton, Ohio. (left) and JANNAF Meeting Chair David Gonzalez, Ph.D., Naval Surface Warfare Center, Indian Head Explosive Ordnance Disposal Technology Division, Indian Head, Md. (right).

ceremony by presenting a PSHS Special Recognition Award to Jamie Fisher, CCDC Aviation & Missile Center (retired), at Redstone Arsenal, Ala., for her technical work on insensitive munitions (IM) in the DoD and her leadership in the PSHS TSG. Ed Vaughn accepted the award on Fisher's behalf.

PEC Co-chairs Christine Michienzi (right), Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, Department of Defense, Alexandria, Va., and Robert Champion (left), NASA Marshall Space Flight Center, Huntsville, Ala.

Dayton Meeting Subcommittee Review

CS

The 49th Combustion Subcommittee hosted 14 technical sessions and held one joint session with the JANNAF Propulsion Meeting (JPM). During the week, 78 papers were presented, four panel or town hall meetings were held, and one workshop on propellant burn rate measurement started off the week. The Combustion Subcommittee continues to be interested in hearing about the community's needs and about advances in propellants and fuel burning, along with the associated modelling efforts to understand the combustion process. The continued development of green propellants and their long-term behavior were topics of several sessions. CS also has interest in the hypersonics area, with two sessions on the science of scramjet engine cold starts.

APS

The 37th Airbreathing Propulsion Subcommittee hosted 17 technical sessions with 79 papers and presentations, along with 11 workshops, specialist sessions, and panel meetings as part of a very full week. Topic areas spanned the full range of the airbreathing propulsion field from design methods for hypersonic vehicles to advanced combustion control devices and testing of medium-scale critical components. There were specialist sessions and workshops on developing improved design methods for hypersonic vehicles, and pressure gain combustion developments. APS teamed up with the Combustion Subcommittee and the Exhaust Plume and Signatures Subcommittee for town hall meetings to discuss common topics within their areas of focus. Finally, the reinvigorated Structures and Materials Panel hosted two technical sessions and a panel meeting.

EPSS

The 37th Exhaust Plume and Signatures Subcommittee hosted seven sessions including a number of joint specialist sessions with Combustion Subcommittee (CS) and Airbreathing Propulsion Subcommittee (APS). In order to accurately model signatures, the EPSS community must first model the demanding environments in which vehicles and systems operate. These environments include plume hypersonic flowfields as well as freestream-body-plume interactions and turbulent chemistry for both internal and external flows.

Accurate modeling of phenomenon requires precise data against which to compare and validate model solutions. New propellants and propulsion systems are a particular challenge as datasets with which models may be compared do not yet exist. AF-M315E is a new green monopropellant that made its inaugural flight on the Green Monopropellant Infusion Mission (GPIM) spacecraft in June (see GPIM Launch, page 14). Measurements of AF-M315E monopropellant thruster plume temperatures and signatures were presented at the JANNAF meeting. Accurate signature models require not only temperature data but also accurate information regarding chemical species concentrations and radiance. These values are strongly affected by environmental factors and papers at the meeting focused on high-altitude measurements and hypersonic flowfield measurements.

Modeling efforts by the EPSS community are broken into plumes and signatures. To obtain accurate signature predictions one must first accurately model the plume, and, to accurately model the plume, the environment, vehicle wake, and internal nozzle flow must all be taken into account. The efforts of the community have resulted in computer models that are utilized not just for signatures, but also for base heating analysis for vehicles, plume impingement for spacecraft and sensor contamination, and rocket nozzle performance, to name just a few. Collaborative efforts are one of the primary focuses of both EPSS and JANNAF as a whole; these fundamental physics and chemistry problems are applicable to many disciplines in spacecraft, propulsion, vehicles, and weapon systems. The JANNAF forum allows the DoD, NASA, and their industry partners to collaborate on new model capabilities that serve a broad base of applications for each of the services and NASA. In addition to the Army, Navy, NASA, and Air Force, which are the namesakes of JANNAF, the Missile Defense Agency presented research to the plume and signatures community highlighting their efforts to develop next generation models for accurate prediction of plume flowfield and signature phenomenon.

One particular topic of broad interest resulted in a joint workshop between EPSS, CS, and APS on turbulent chemistry. Topics included high-pressure turbulent combustion, plume afterburning, chemical mechanisms, and turbulence-chemistry interactions. It is important to recognize that the concept of "plume" can be applied not only to rocket exhaust plumes, but also to the wakes of hypersonic vehicles, and muzzle blast from gun propulsion systems; the challenges involved in modeling these phenomena and then applying those models to the development and/or analysis of systems are shared between these subcommittees.

Participation in EPSS sessions in Dayton was the largest since the heydays of TDK (Two Dimensional Kinetic), SPP (Solid Propellant Rocket Motor Performance Prediction Computer Program), and VIPER (Viscous Interaction Performance Evaluation Routine) codes. The community continues to push the envelope on capturing the physical, chemical, and radiative effects associated with rockets and hypersonic systems; yet there remains much work to be done and limited resources with which to do it. The leadership of the JANNAF EPSS Technical Steering Group recognizes that these technologies are of critical national importance and that no single agency is capable of shouldering the burden alone.

PSHS

The 31st Propulsion System Hazards Subcommittee hosted six technical sessions and four panel meetings. A two-part technical session on shock and impact-induced reactions, which was a follow-up to a PSHS-sponsored workshop in 2018, included a summary of a PSHS panel task: "Investigation of Gap Test Modeling and Instrumentation." A two-part session on energetic liquid hazards addressed the development of NATO standardization agreement (STANAG) 4751, among many other liquid fuel safety issues. The technical session and panel meeting on insensitive munitions served to inform the community about new approaches to insensitive munitions related programs, including a review of the newly renamed Joint Enhanced Munitions Technical Program. PSHS closed the week with a Technical Steering Group meeting that addressed ongoing and future subcommittee activities and changes in membership.

MSS

The The Modeling and Simulation Subcommittee held a full week of sessions, workshops, and specialist sessions out of phase from the current meeting schedule. The MSS met with the JPM for the meeting in Dayton. The main topics that were covered were:

- Rotating detonation rocket engines (RDRE) ideal performance metrics
- Digital engineering
- Model verification, validation, and uncertainty quantification
- Digital twins and augmented reality for solid rocket motors and strategic fleet maintenance
- Code demonstrations of VULCAN (Viscous Upwind Algorithm for Complex Flow Analysis) and Kestrel

Each session was well attended, especially the Monday morning RDRE performance metric specialist session, which was standing room only. Ideal performance metrics for RDREs are required in order to establish performance baselines for rotating detonation engines. Ideally, the performance metrics will be agreed upon and published through JANNAF. The RDRE session served as a precursor for a workshop that will be held at the December JANNAF Meeting to discuss advancing these metrics.

The Digital Engineering group held a plenary talk by Tracee Gilbert, Ph.D., followed by Col. Paul Harmer on strategic plans for Digital Engineering in the Office of the Undersecretary of Defense (OSD) and the Air Force, respectively. The two talks were very well received, and a discussion with the digital engineering community was held between the two. The session included more than an hour of time for the technical community and the upper management of the DoD to interface one on one.

There was also a session held on augmented reality as part of the Digital Engineering topic. This session specifically addressed training employees, aiding maintenance workers, and tracking the condition of fleets of aircraft, strategic missiles, and other high priority inventories. A second session demonstrated current capabilities in digital twin inventory and augmented reality aid in maintenance for Northrup Grumman's strategic missile fleet. The session included a live demo of sen-

(See Dayton Subcommittee Review on page 12

JHU ERG's Meetings Team

You may recognize the names Shelley Cohen and Gabrielle Delisle if you attend JANNAF meetings. Together, they serve the JANNAF community on the Johns Hopkins Energetics Research Group Meetings Team. They both take care of many tasks required to make each meeting a success, including communicating with meeting attendees about details for upcoming JANNAF meetings, and ensuring proceedings from the meeting are available for viewing after each meeting is complete.

Cohen, JANNAF Meeting Manager, is responsible for overall tasks of the meetings: researching, selecting and negotiating contracts for meeting venues, hotels, and various vendors; running the JANNAF Program Planning Committee Meeting to schedule sessions; planning and communicating logistics for all food and beverage, meeting room set-ups, and audio-visual support to the hotel and other vendors throughout the meeting cycle; gathering local restaurant, transportation and entertainment information on meeting locations to provide to attendees; and she serves as the primary point of contact before, during, and after the meeting for registration and payment purposes.

Delisle will be attending her second meeting in Tampa, FL. She joined the team in March of 2019. She creates the meeting websites that allow you to register for the meetings; creates and sends meeting invitations, calls for papers, preliminary programs; designs the final program; executes all program changes; creates posters and other graphics for meetings; designs and orders notepads, pens, lanyards and other items handed out at registration; and collects papers and presentations for JDOC.

Shelley Cohen, JANNAF Meeting Planner

Gabrielle Delisle, Assistant Meeting Planner

Chances are if you are attending the upcoming JANNAF meeting, you have heard from or communicated with both Shelley and Gabrielle in the past few months. Stop by to say hello to them near the registration area in Tampa.

Dayton Subcommittee Review... *continued from page 11*

sors and software interfacing in a real-life scenario.

Code demonstrations were held to show the community how VULCAN and Kestrel operate. Hypothetical scenarios were used to demonstrate the capabilities of each code, and the community expressed interest in creating a user group. The code demonstration session was a continuation of a well-attended session at the May 2018 JANNAF meeting in Long Beach, Calif., on FEM (Finite Element Method) Builder, ROCETS (Rocket Engine Transient Simulation) and HERO (Heat Transfer and Erosion Analysis Program). Continued sessions will be held at the December 2019 JANNAF Meeting (see Tampa Subcommittee Highlights, pages 4-5, for more information).

A few Technical Steering Group (TSG) updates occurred at the Dayton MSS TSG meeting. Eric Paulson, Ph.D., Air Force Research Laboratory, Edwards Air Force Base, Calif., will be stepping down from the TSG at the December JANNAF Meeting in Tampa. He will be transferring to the Liquid Propulsion Subcommittee (LPS) to continue his work on RDREs. Paulson has supported the MSS TSG for more than a decade – including serving as chair for six years. MSS wishes him well with continuing his efforts under LPS. Scott Hyde, Northrop Grumman Corporation, Brigham City, Utah, will also be stepping down as panel and mission area chair from the Integrated Health Management Panel and mission area. Hyde has overseen the panel since MSS's formation. He has provided many years of expertise in modeling, sensors, and solid rocket motors. He was a key proponent for creating the JANNAF Sensors Database.

ERG Staff Member Selected for Service with National Academies' Board

Johns Hopkins University Energetics Research Group (ERG) Associate Research Engineer William A. Bagley has been selected by the National Academies of Sciences (NAS), Engineering, and Medicine to serve as a member of the Board on Army Research and Development's Energetics Roundtable. The NAS's Energetics Roundtable, which meets up to four times per year, includes subject matter experts from U.S. government agencies, the Department of Defense, military service branches, academia, and industry. The organization's mission is to provide a forum for discussing U.S. Army "energetic needs and the attendant sciences and policies that may accelerate or advance capabilities in this domain." The Energetics Roundtable is sponsored by the Office of the Deputy Assistant Secretary of the Army (Research and Technology) and reports its findings to the Board on Army Research and Development. Speaking of his June 2019 appointment, Bagley said "It is an honor to be included in the NAS Energetics Roundtable as part of a group that includes senior members of the energetics community. The Academy did an amazing job of bringing together subject matter experts that represent the various elements of energetics research. I am particularly impressed with the forethought of seeking input from the EOD [Explosive Ordnance Disposal] community, typically only an afterthought, as the groups work to advise the future of energetics in America."

Johns Hopkins University Energetics Research Group Associate Research Engineer William A. Bagley.

ERG Staff Participate in International Explosive Ordnance Disposal Symposium

Johns University Energetics Research Group (ERG) staff participated in the 2019 Global Explosive Ordnance Disposal (EOD) Symposium & Exhibition, which took place from 6-8 August 2019 in Bethesda, Md. The annual event was produced by the National Defense Industrial Association in partnership with the EOD Warrior Foundation. The theme of the 2019 symposium was "Innovation for the Future" and the presentations, panels, and workshops were intended to provide valuable information in support of the EOD, public safety bomb squad, and unexploded ordnance and demining communities. Col. Leo Bradley, U.S. Army (retired), who serves as an ERG consultant, served as the chair of the event. Major General Randy Manner, U.S. Army (retired), also an ERG consultant, chaired a workshop on military-to-civilian transition for EOD professionals. ERG Associate Research Engineer William Bagley served as humanitarian mine action (HMA) chair and also moderated a panel focusing on academic support for HMA. Bradley and Bagley also helped to organize the three-day symposium, which included numerous sessions for EOD professionals on means for detecting explosives and weapons of mass destruction, counter-improvised explosives technologies, blast effects, ordnance disposal and demining, brain health, and suicide prevention. Johns Hopkins University Applied Research Lab staff also participated in the symposium and exhibition.

Green Propellant Mission Launches Successfully

Early on the morning of Tuesday, June 25, 2019, the flames from a SpaceX Falcon Heavy rocket lit up the darkness of Kennedy Space Center Launch Complex 39A. The Falcon Heavy hosted the Department of Defense's (DoD) Space Test Program-2 (STP-2), a multi-manifest mission involving DoD, National Aeronautics and Space Administration (NASA), and National Oceanic and Atmospheric Administration (NOAA) satellites, along with a number of satellites from educational institutions and the private sector. For the spacecraft propulsion community, NASA's GPIM (Green Propellant Infusion Mission) satellite was a particularly important and long-awaited component of the Falcon Heavy launch manifest. Funded by NASA's Technology Demonstration Missions program within the agency's Space Technology Mission Directorate, the satellite was built by Ball Aerospace & Technologies Corp. based on the company's "smallsat" design. The GPIM satellite will serve as a testbed for the high performance, non-toxic (i.e., "green") AF-M315E propellant (also known as ASCENT (Advanced Spacecraft Energetic Non-toxic Propellant)) developed by researchers at the Air Force Research Laboratory at Edwards Air Force Base, California, with funding from the Air Force Office of Scientific Research. The satellite's thrusters were developed by Aerojet Rocketdyne and the AF-M315E-based propulsion system was co-designed by Ball Aerospace and Aerojet Rocketdyne. Over the next 13 months, the GPIM satellite will perform a number of in-orbit maneuvers, including attitude control, spacecraft pointing, thruster performance characterization and mapping, and orbit lowering, to test the efficacy of the AF-M315E-based propulsion system and demonstrate its viability for future government and commercial spaceflight missions

"A Long Anticipated Launch"

The morning of June 25, 2019, was a very special event for a small group of researchers at the Air Force Research Laboratory, Edwards Air Force Base, California. The long awaited and anticipated launch of Space X Heavy Lift Rocket carrying the GPIM Satellite loaded with AFRL-developed AF-M315E monopropellant had finally arrived.

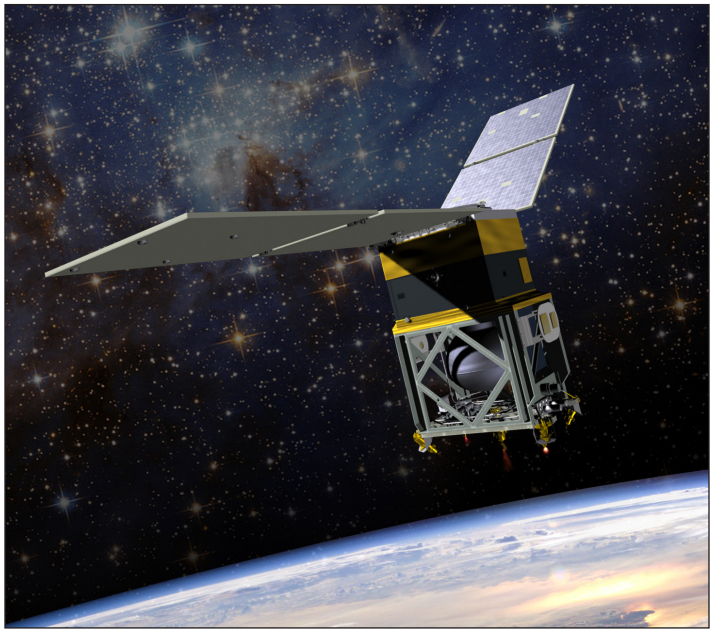


Illustration of GPIM spacecraft in orbit. Image courtesy NASA.

AF-M315E was the result of twenty-plus years of tests and evaluation of ingredients and formulations by a small team of Chemists and Chemical Engineers led by Dr. Tommy Hawkins. Tommy's early research with ionic liquids, both energetic and non-energetic, lead his desires towards an "environmentally" friendly, safe, and more energetic replacement for the hazardous and caustic SOTA propellants used in the 1960's and 1970's. The "fuel" component of AF-M315E Monopropellant consisted of a new and novel compound developed by Dr. Hawkins under testing in the mid-1990's, while the oxidizer, HAN, was already on the scene, but formulated and "tweaked" to work in the final formulation by Adam Brand, co-inventor of AF-M315E. Naming potential monopropellant formulations through the years was easy. "Air Force-Monopropellant"… followed by a team /family members birthday or wedding anniversary.

I was fortunate enough to be on this talented team of government and defense contractors that worked together to formulate, test, re-test, and re-evaluate a multitude of new compounds and mixtures to end up with what is now in Earth's orbit.

Milton McKay

"It has been a long wait"

The emerging "green" spacecraft monopropellants offer real alternatives to hydrazine which has been around since the 1970's. Due to the risk averse nature of the space launch industry, a successful launch and demonstration of GPIM has really been key to capturing interest from the community. GPIM demonstrated the total ground operations cycle with the introduction of ASCENT monopropellants with an established propellant specification; shipping standard; safety data sheet; materials compatibility; decontamination standard; tailored Propellant load Ground Support Equipment (PGSE) design and build; and established operations procedures and checklists in compliance with requirements documents. Introduction of a new energetic material to the launch environment mandated additional upfront effort. However, this effort will not be required to be repeated to the same extent for follow-on missions. Of notable significance was the significant reduction in disruption of peripheral pre-launch payload operations to other payloads sharing the payload processing facility. It has been a long wait, but now potential customers are coming forward in addition to companies wishing to mature the technology. In the near term, the ease of handling and the inherent higher densities of these propellants make them particularly attractive for certain volume-limited spacecraft like smallsats and cubesats. The higher energy density translates into either longer time on orbit for a given volume or a smaller package.

Chris McLean (right), Principal Investigator for GPIM at Ball Aerospace, and Joe Cassada (left), Executive Director of Space at Aerojet Rocketdyne, discussing the GPIM mission. Photo courtesy NASA/Frank Michau.

Adam Brand and Paul Zuttarelli

Portions of this article will appear in a future edition of the DSIAC Journal. The JANNAF News would like to thank Adam Brand, Milton McKay, and Anthony P. Zuttarelli for their contributions to this article.

ERG Offers JANNAF Technical Products and Services

The Energetics Research Group (ERG) at Johns Hopkins University 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.

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, JANNAF collaborative workspaces, and more than 26,000 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.

The ERG also accommodates individual requests from qualified non-ERG subscribers for its products and services. Payment methods include check or money order (made payable to the Johns Hopkins University), and VISA, Mastercard, and American Express credit cards.

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.

Modeling and Simulation Subcommittee: Advancing the Basis of Digital Engineering

From the Director's Desk:

JANNAF has a long history dating back to the end of the Second World War; since before the formation of the Department of the Air Force and NASA, JANNAF has served as the U.S. Government's primary means to ensure collaboration and information exchange between departments and agencies engaged in propulsion, munition, and space programs and research. It is an honor to serve as the Director of ERG in support of JANNAF's mission, a mission that the Johns Hopkins University has shared with JANNAF since its inception.

Prior to becoming the Director of ERG, I served as one of CPIA's technical staff in support of JANNAF Subcommittees; a role that engineers at JHU have served for over seven decades and continue to serve today. It was my privilege to be involved in the formation of the LPS & SPS subcommittees and to serve as an early liaison to MSS.

What follows is the first of a series of articles in the JANNAF News *looking back on the history of JANNAF subcommittees and the vision for their role in the future of propulsion and energetics. As members of the propulsion community, each of us has played a role in continuing to make JANNAF a vibrant and relevant organization. I look forward to many more years of successful collaboration.*
Peter E. Zeender

The JANNAF Interagency Propulsion Committee established the Modeling and Simulation Subcommittee (MSS) in 1999 to promote, facilitate, guide, affect coordination, and focus on problem solving in the areas of modeling and simulation for propulsion systems of joint agency interest. Investigators' ability to build computer models of complex propulsion systems is dependent on their ability to solve complex, nonlinear engineering equations. In these research approaches, such as structural dynamics and computational fluid dynamics, it is computationally expensive to employ large mathematical meshes with several engineering equations defining the multiple inputs and outputs of the model. Even simple meshes can take days to run and more complex meshes can take weeks or more to produce results. New methods for solving equations and optimizing models were needed by the propulsion community to more accurately simulate propulsion systems, their components, and integrated health management. Additionally, the value of modeling and simulation depends on the credibility of simulations for making effective decisions.

Origins of MSS

From 1991 to 1999, the JANNAF Airbreathing Propulsion Subcommittee (APS) held workshops on modeling and simulation, specifically on computational fluid dynamics (CFD) code validation/calibration. John L. Porter, Ph.D., of Sverdrup Technology, Inc., located at Elgin AFB, Fla., chaired these workshops. They were held under the auspices of the Airframe Integration Panel from 1991 to 1996, and subsequently the Modeling and Simulation (M&S) Panel. Porter was presented the JANNAF APS Recognition Award in 1997 for his involvement with these efforts.

The M&S Panel had the following technical objectives: standardize analysis procedures for valid and useful modeling and simulations associated with ramjet, scramjet, and combined cycle engines; standardize modeling and simulation nomenclature, protocol, and operational practices, and catalog and evaluate archival data; assist users with JANNAF-sponsored models and simulations; and develop techniques and procedures to deal with modeling and simulation needs, and problems related with airframe integration, engine cycle analysis, aerothemochemical analysis, and testing of propulsion systems.

In July 1998, Porter, as co-chair of APS's M&S Panel, proposed to the JANNAF Executive Committee (EC - now known as the Technical Executive Committee (TEC)) that the M&S Panel be elevated to full JANNAF subcommittee level. The mission statement of the new subcommittee would be to serve the entire JANNAF community's needs by including members from each of the JANNAF subcommittee technology areas, and by ensuring that M&S processes and procedures would be valid and useful, with

a focus on fundamental processes and systems. The subcommittee's purpose was to provide a forum for government, industry and academia to jointly investigate and share technical M&S information and data; establish processes on standards and procedures for implementation of M&S policy; and to affect the coordination of government-funded M&S programs. Two panels were proposed: M&S for Fundamental Engineering and M&S of Integrated Systems.

The EC twice held open the decision to create the new M&S Subcommittee pending the justification for its need and further definition of the charter, scope, and relationship to the other subcommittees. APS tabled its effort to create MSS. The proposal to create the MSS was on the agenda for the December 1999 EC meeting. Porter resigned as the APS M&S Panel co-chair in November 1999.

APS Technical Steering Group (TSG) Chair Charles McClinton, NASA Langley Research Center, requested Unmeel B. Mehta, Ph.D., NASA Ames Research Center, to advocate for the creation of MSS with the EC. A new vision and strategy were presented. Current M&S activities were identified based on subcommittee mission and scope statements, as well as 1999 annual subcommittee reports to the EC; rationale for the creation of MSS was addressed; and details regarding mission, scope, and objectives of panels for the proposed subcommittee were discussed. M&S for understanding phenomena and propulsion components and for developing components of propulsion systems was excluded, since other subcommittees covered these subjects.

EC Chairman Stuart Blashill, NAWCWD, China Lake, Calif., approved the formation of MSS in December 1999, with Mehta serving as its first TSG Chairman. APS would continue to support its own M&S Panel.

In November 2000, Mehta, presented an overview of the new subcommittee to the joint JANNAF Meeting attendees in a Plenary Session at its first subcommittee meeting, jointly with the Combustion Subcommittee (CS), APS, and Propulsion Systems Hazards Subcommittee (PSHS). Eighteen papers were presented in four MSS sessions held at the meeting in the following technical areas: Uncertainty Assessment and Management, Virtual Engineering, and Integrated Vehicle Health Management; and thirteen papers were also presented in two joint sessions with the APS and CS. Subsequently, these subcommittees held three joint meetings, with the last one occurring in June 2005.

The original scope as presented to the EC in 1999 was refined after the first MSS Meeting. System integration of air-breathing propulsion systems was excluded and the scope of integrated health management was narrowed in order to focus on propulsion systems. The first Annual Report of the MSS to the EC, in November 2002, presented its vision, mission, and scope:

I. Vision

This subcommittee will promote, facilitate, guide, affect coordination, and focus on problems in modeling and simulation of propulsion systems leading to significantly reduced acquisition time, total life-cycle cost, and risk.

II. Mission

This subcommittee exists to promote and facilitate exchange of technical information; establish guides, procedures, and standards; affect coordination of research, exploratory development, advanced development, and engineering; and focus on solving problems in the area of simulation based acquisition through the creation of virtual reality for spaceplane, globecruiser, rocket, and missile and for in-space and gun propulsion of joint agency interest.

III. Scope

The propulsion-related modeling and simulation activities include systems integration, virtual engineering (VE), integrated health management (IHM), and uncertainty assessment and management. Modeling and simulation range from hard computing to soft computing to knowledge-based computing and from ground-based testing to subscale-flight testing. Modeling and simulation activities include also the development of procedures, guides, and standards.

The specific technical objectives of the current MSS Panels are summarized below:

A. Systems Integration Panel – Systems Integration includes integration of subsystems into a propulsion system, integration of the propulsion system with other systems to form a system of systems, and system life-cycle cost analysis. The panel objective is to identify the state of the art in modeling and simulation for systems integration. This includes identifying the important analysis disciplines and interactions, assumptions made, their level of influence or importance, interaction, and range of validity for each assumption.

(See MSS Overview on page 18)

B. Virtual Engineering Panel – Virtual Engineering (VE) includes virtual prototype, virtual test, and virtual manufacturing. The panel objective is to advance VE as an integrated design and analysis tool that would enable "real time" analyses to facilitate rapid design, undertake multidisciplinary analysis, and complete mission predictions & manufacturing simulations.

C. Integrated Health Management Panel – Integrated Health Management (IHM) includes IHM system design, vehicle safety, and intelligent systems. The panel objective is to provide a forum to promote advancement and creation of industry practices for Integrated Health Management (IHM) of propulsion systems to reduce the cost of maintainability and increase the reliability of propulsion systems.

D. Uncertainty Assessment & Management Panel – Uncertainty Assessment & Management includes sensitivity-uncertainty analysis, experimental uncertainty, simulation uncertainty, model uncertainty, and risk analysis. The credibility assessments of models and simulations include verification and validation. The panel objective is to provide a forum to assess and develop uncertainty assessment and management methods for digital and analog modeling and simulation.

These vision, mission, and scope statements have essentially remained the same. The names of three of the aforementioned panels evolved to Model Based System Engineering (MBSE) (combining the Systems Integration Panel and the Virtual Engineering Panel) and Simulation Credibility (SC). The specific scopes of the IHM and SC continue to be the same and that of MBSE changed to encompassing the model-based conceptual design, performance prediction, and system analysis of vehicle system technologies and their flight systems.

Mehta received a JANNAF Executive Committee Special Service Award in December 2006 for his "tireless leadership and boundless enthusiasm" as the first chairman of the JANNAF Modeling and Simulation Subcommittee.

Current MSS Focus

The MSS community has made major efforts to quantify uncertainties, develop methods to verify and validate models with respect to real physical systems, and establish the credibility of the results from the uncertainties and verification/validation results. MSS efforts over several years led to the publication of "Simulation Credibility: Advances in Verification, Validation, and Uncertainty Quantification" (NASA/TP—2016–219422 or JANNAF/GL—2016–0001, JDOC Abstract Number: 2016-0002), a groundbreaking guide for assessing simulation credibility.

MSS is also advancing rapidly into the realm of Digital Engineering, a concept that takes models and simulations already used by the propulsion community and adds key overarching concepts, such as the integration of full system models (i.e., Model Based Engineering (MBE)), integrated health management (seen as a source of information for condition-based maintenance and fielded systems representations), simulation credibility, and system autonomy. MSS has recently revised its mission areas to include these four topics.

MBE encompasses the development of methodologies, codes, and model simulations to quantitatively evaluate and optimize propulsion technologies across propulsion components, propulsion systems, and vehicle systems levels. The MBE mission area includes the specific discipline of MBSE. MBSE is the formalized application of modeling to support system requirements, design, analysis, and verification/validation activities from conceptual design through later life cycle phases. The use of models complements traditional experimentation during the technology development phase by reducing the necessary development time. Developing and using physics-based models allows investigators to explore domains and behaviors that may be particularly difficult or impossible to examine experimentally. Publications in the MBE area fall under two topic headings: Modeling Methodologies/Approaches/Tools and System Analysis Results.

IHM promotes the development and advance of industry practices for managing the health of propulsion systems within a "system of systems" environment. IHM includes methods and tools for data management and mining, integrated command and control, sensors, diagnostics, and prognostics. These tools permit investigators to make redline and contingency decisions using knowledge-based expert systems, model-based diagnostics and reasoning, fault

models, neural networks, fuzzy logic, genetic and evolutionary algorithms, and life-cycle analysis.

The credibility of digital and analog simulations is a major issue for incorporating simulation tools and data into technology-development programs; for conducting simulation-based acquisitions; for assessing system reliability to assure human safety and/or mission success; and for identifying and assessing risks in complex, technological systems. Simulation credibility includes assessing and managing computer simulation uncertainty, sensitivity-uncertainty analysis, experimental uncertainty, modeling uncertainty, verification and validation (V and V) of simulation models and simulations, and risk assessment.

Modeling and Simulation of System Autonomy encompasses the development of methodologies; codes; models; and simulations to evaluate, analyze, and optimize autonomous system capabilities. System autonomy addresses the modeling and simulation of artificial intelligence (AI) algorithms; the integration of AI algorithms; simulation environments including the interaction of algorithms with system hardware; verification and validation of non-deterministic algorithms; and determination of operational bounds. Using modeling and simulation of autonomous systems to determine responses and operational bounds is also critical. Various autonomous systems are included in this mission area including aircraft, ground vehicles, hypersonic vehicles, launch vehicles, spacecraft, submarines, and sea surface ships.

Within the propulsion community, there is a growing dependence on models and simulations to reduce the cost and time needed for full-scale system development and testing. This trend is evident in both vehicle and propulsion system applications. Government and industry must ensure that testing is done to verify and validate the models and simulations currently employed by investigators, both ensuring that they are relevant to the system and proving that they adequately represent the system. As these propulsion and system models become the basis for the development and production of increasingly complex systems, MSS is providing a forum to discuss and share advances in the field. MSS is focused on providing opportunities for communication within the DoD, NASA, and industry on new modeling efforts, ultimately providing a venue for modeling and simulation experts to review and comment on new developments in the field and return to their home organizations with new knowledge and skills in order to advance modeling and simulation capabilities for the propulsion community as a whole.

MSS has continued to focus on supporting all of the JANNAF subcommittees with advances in modeling and simulation capabilities. In 2017, discussions with each of the subcommittee chairs were held that identified a number of mutually interesting topics. Among the interests identified were demonstrations of relevant government-developed tools, benchmarking of tool platforms as computing technology continues to change, and analysis requiring model integration methods. MSS is currently working to incorporate these focuses in the Mission Areas. Based on this discussion, MSS is looking to shift to meeting annually to enable collaboration with all of the JANNAF subcommittees over a three-year period. MSS has also begun sponsoring demonstrations of government-funded tools relevant to the subcommittees supporting each JANNAF Propulsion Meeting. These demonstrations have been well attended with one modeling user's group requested as a result of the demonstration. As MSS moves forward, the subcommittee continues to seek to "serve the entire JANNAF community's needs," as stated in the original proposed mission statement.

The JANNAF News would like to thank Unmeel B. Mehta, Ph.D., and Michael D. Watson, Ph.D., for their valuable contributions to this article.

JANNAF is pleased to announce the Best Student Paper from the June 2019 JANNAF Meeting

"Investigation of a Hypergolic Dicyanoborohydride-Based Ionic Liquid"

Student/Primary Author:
Anna E. Thomas, Ph.D., Stanford University, Stanford, Calif.

Authors:
Anna E. Thomas, Ph.D., Stanford University, Stanford, Calif.; Stephen D. Chambreau, Ph.D., ERC, Incorporated, Edwards AFB, Calif; Alan A. Esparza Hernandez, Ph.D., and Evgeny Shafirovich, Ph.D., University of Texas at El Paso, El Paso, Texas; and G. L. Vaghjiani, Ph.D., Air Force Research Laboratory, Edwards AFB, Calif.

JANNAF Community Recalls 1969 Moon Landing

I was seven years old when Apollo 11 launched from Kennedy Space Center on July 16, 1969, and landed on the Moon four days later. I remember being into NASA and building plastic models, so I had my own Saturn V and Lunar Module space models that I "flew" along with the Apollo 11 astronauts on their mission, and I was mesmerized by the images from the mission. Seeing the astronauts in their futuristic white spacesuits blasting off on the giant Saturn V to another world got me excited about NASA and human exploration of other worlds. My friends and I played being astronauts and pretended to go exploring the final frontier on our own. When I was asked what I wanted to be when I grew up, the answer stayed the same – become an astronaut, fly rockets for NASA or be an oceanographer exploring the world beneath the sea. My military family traveled to many places, and I got to see many airplanes, helicopters and tanks, but I will never forget getting to touch a Moon rock for the first time. It inspired me to study math and science as hard as I could, so that I could become an astronaut. I didn't quite realize that dream, but I did become an engineer for NASA's Marshall Space Flight Center in Huntsville, Ala. My career did include getting to don a futuristic white spacesuit for underwater EVA testing in Marshall's Neutral Buoyancy Facility, and I also worked as a support diver for astronaut training. I have never lost my love for rockets, and I am very proud to be working on NASA's and America's next rocket, the Space Launch System, that will be the largest and most capable rocket in the world. I can't wait to watch the Artemis 1 mission blast off the launch pad, when the eyes of the world will again see America on the way to the Moon for our nation's next great adventure in space.

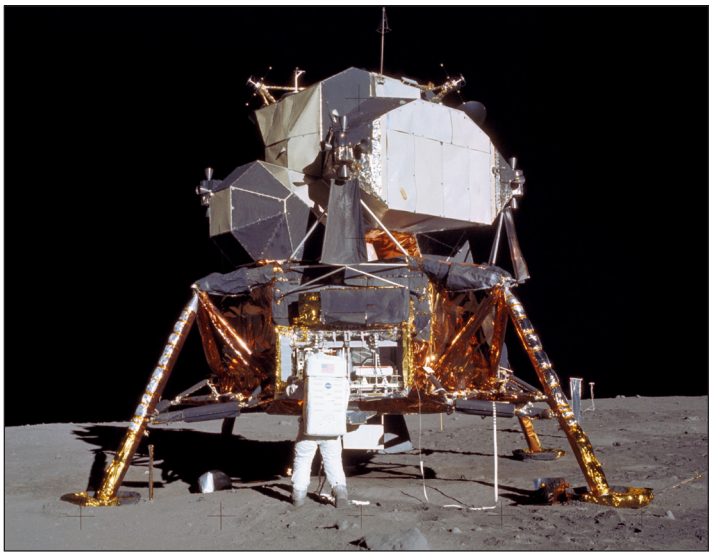
Bruce R. Askins, NASA Marshall Space Flight Center, Huntsville, Ala.

Astronaut Edwin "Buzz" Aldrin descends a ladder from lunar module Eagle in a July 1969 photograph taken by astronaut Neil Armstrong. Photo courtesy NASA.

"It inspired me to study math and science as hard as I could."

I'm writing this paragraph wearing a T-shirt I've owned for 30 years which says, "Return to the Moon and Stay!" In the 1950s I grew up on a diet of science fiction, Popular Mechanics, and the now iconic space illustrations of Chesley Bonestell. In elementary school I made my own rockets using hobby shop chemicals and even launched one for fourth grade show and tell. One glorious day in 1957 I got to hear Sputnik beep over a friend's ham radio. In the 1960s I followed Mercury and Gemini religiously and cried after the Apollo 1 fire. I watched every episode of the original Star Trek and went to the studio to protest with most of the UCLA physics department when it was cancelled after the second season. (So, you can partly blame me for the less than wonderful partial third season.) And, in the summer

"Two images were indeliby burned into my memory – Walter Cronkite choking up with emotion, and Neil Armstrong coming down the ladder."



Astronaut Edwin "Buzz" Aldrin prepares experiments, July 1969. Photo courtesy NASA.

of 1969 I arranged my Sierra backpacking schedule so I would be out of the mountains in time to see Apollo 11 land on the moon. A friend and I were serving as John Muir Trail guides all that summer, but there was no way I would miss the landing. So, we scheduled a resupply stop for Onion Valley outside of Independence, Calif., and we had prepositioned my friend's car so we could drive to the "big" town at the foot of the mountains. We watched the landing and the walk from a small bar (no, we were not yet 21) and two images were indelibly burned into my memory – Walter Cronkite choking up with emotion, and Neil Armstrong coming down the ladder. I had wanted to be an astronaut before that moment, but that confirmed the desire. However, I had to "settle" for the next best thing. Along the way I got to meet Buzz Aldrin, John Young, Jim Lovell, Chuck Yeager and several other astronauts and X-15 pilots and be associated with the incredible crew of scientists, engineers, and technicians who have made NASA tick. I can only hope I will live long enough to see the wish on my T-shirt come true.

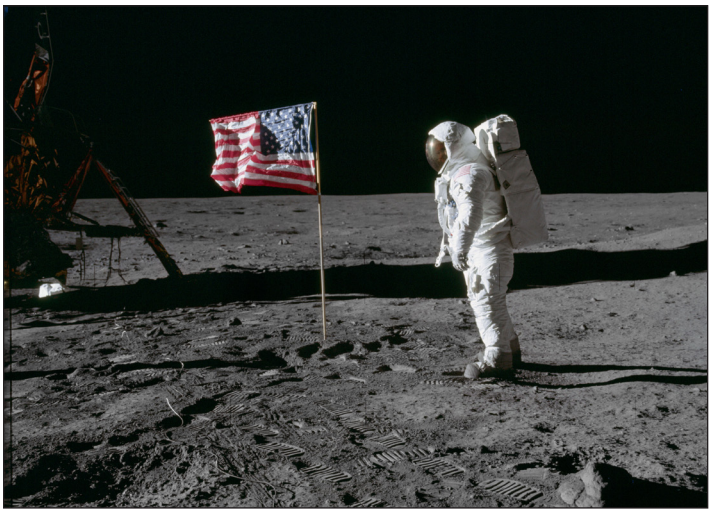
Stuart R. Blashill, ERG, Columbia, Md.

From an early age, I knew I wanted to be an aeronautical engineer. I remember when the Boeing 707 was brought into service: they were big, sleek and beautiful. That made up my mind for a career. I remember Sputnik, which caught the U.S. by surprise. I also remember Telstar, which actually relayed communications over the Atlantic. And I remember the space race between the US and Russia. I remember John F. Kennedy's inaugural and moon speeches. I remember watching Mercury, Gemini, and Apollo launches. I saw the LEM for Apollo 10 under construction at Grumman in Bethpage, N.Y., and thought about how fragile it looked. And I remember watching the Apollo 11 moon landing on TV. We Americans had beaten the Russians to the moon, the real prize in the space race. It was almost surreal watching Neal Armstrong and

"We had done the 'impossible' in such a short time. This strengthened my resolve to be an engineer."

Buzz Aldrin descend the ladder (the struts on the LEM had not compressed as much as was thought), plant the American flag, and take samples. We had done the "impossible" is such a short time. This strengthened my resolve to be an engineer. My career took me to Los Angeles to work on satellite design and survivability, then to Wright-Patterson to analyze aircraft and weapon survivability and lethality, then ducted rockets, and finally hypersonics. I carry a sense of service from J.F.K.'s inaugural (that quote is on my desk for all to see). I carry a sense of drive and positive can-do from his moon speech. And I carry a sense of wonder from seeing two men walk on the surface of the moon and know we can do anything that we really want to do, not because it is easy but because it is hard.

Robert A. Mercier, AFRL, Wright-Patterson AFB, Ohio



Astronaut Edwin "Buzz" Aldrin next to American flag at Tranquility Base. Photo courtesy NASA.

JANNAF Journal of Propulsion and Energetics

The Call For Papers is Ongoing

Submit your manuscript NOW for consideration in

Volume 11

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

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

Gabrielle Delisle
Assistant Meeting Planner
gdelisle@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

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

Karolyn Del Favero
Software Engineer
kdelfavero@erg.jhu.edu / 410-992-7304 ext. 220

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/*JANNAF News* Editor
bschwantes@erg.jhu.edu / 410-992-7300 ext. 227

TECHNICAL REPRESENTATIVES

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

Kirk Sharp
ksharp@erg.jhu.edu / 228-234-5423

JANNAF Technical Executive Committee

CHAIRMAN

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

ARMY

Dr. Jay S. Lilley
Army CCDC Aviation & Missile Center/
Redstone Arsenal

Dr. Rose A. Pesce-Rodriguez
Army CCDC Army Research Laboratory/APG

NAVY

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

Mr. Frank C. Tse
Naval Surface Warfare Center/Indian Head

NASA

Dr. Daniel J. Dorney
NASA Marshall Space Flight Center/Huntsville

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

AIR FORCE

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

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

EX OFFICIO

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

JANNAF COR

Mr. Carl E. Ousley
Air Force Research Laboratory/EAFB

JANNAF Programmatic & Industrial Base Executive Committee

CO-CHAIRS

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

Mr. Robert H. Champion
NASA Marshall Space Flight Center/Huntsville

ARMY

Dr. Jamie B. Neidert
Army CCDC Aviation & Missile Center/Redstone Arsenal

Mr. David L. Tritt
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/Indian Head

NASA

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

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

AIR FORCE

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

Lt. Col. Shaun Easley
Air Force (A10)/Washington, D.C.

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

DEPARTMENT OF DEFENSE

Mr. Jason Jouet
OSD (R&E)/Washington, D.C.

Mr. David McNiell
Missile Defense Agency (ECD)/Fort Belvoir

Mr. Sean Miller
DCMA (Industrial Analysis Group)/
Philadelphia

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

ERG REPRESENTATIVE

Mr. Kirk Sharp

JANNAF Subcommittee Chairmen and ERG Representatives

Subcommittee/Chair	Deputy Chair	ERG Representative
AIRBREATHING PROPULSION (APS)		
Dr. Jeffrey M. Donbar Air Force Research Laboratory/WPAFB	**Mr. Charles P. Leonard** NASA Langley Research Center	**Mr. Alex Bishop**
COMBUSTION (CS)		
Dr. Heather F. Hayden Naval Surface Warfare Center/Indian Head	**Dr. Ghanshyam L. "Gammy" Vaghjiani** Air Force Research Laboratory/EAFB	**Mr. Ben Hill-Lam**
EXHAUST PLUME and SIGNATURES (EPSS)		
Dr. Milton E. Vaughn Jr. Army CCDC Aviation & Missile Center	**Dr. Kevin D. Kennedy** Army CCDC Aviation & Missile Center	**Mr. Nicholas Keim**
JANNAF PROPULSION MEETING (JPM)		
Dr. David R. Gonzalez Naval Surface Warfare Center/Indian Head	**Mr. Bruce R. Askins** NASA Marshall Space Flight Center	**Mr. Pete Zeender**
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)		
Mr. Charles L. Davis NASA Kennedy Space Center		**Mr. William Bagley**
PROPULSION SYSTEMS HAZARDS (PSHS)		
Mr. Adam J. Brand Air Force Research Laboratory/EAFB	**Dr. Joel B. Stewart** Army CCDC Army Research Laboratory	**Mr. William Bagley**
ROCKET NOZZLE TECHNOLOGY (RNTS)		
Mr. John Robert Esslinger Jr. Army CCDC Aviation & Missile Center		**Mr. Bryan DeHoff**
SAFETY and ENVIRONMENTAL PROTECTION (SEPS)		
Dr. Sara K. Pliskin Naval Surface Warfare Center/Crane	**Dr. David R. Mattie** 711 Human Performance Wing/WPAFB	**Mr. William Bagley**
SPACECRAFT PROPULSION (SPS)		
Dr. William A. Hargus Jr. Air Force Research Laboratory/EAFB	**Dr. Hani Kamhawi** NASA Glenn Research Center	**Mr. Alex Bishop**
STRUCTURES and MECHANICAL BEHAVIOR (SMBS)		
Dr. Jeremy R. Rice Army CCDC Aviation & Missile Center	**Mr. Robert W. Pritchard** Naval Air Warfare Center Weapons Division	**Mr. Bryan DeHoff**

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. "Chuck" 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/Indian Head

ELECTRIC PROPULSION

Mr. David T. Jacobson
NASA Glenn Research Center

SCIENCE and TECHNOLOGY

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

TEST and EVALUATION

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

Exhibit and Sponsorship Details

Sponsorship Packages

"Tier III" Sponsorship / $1,500
- 50% discount on registration ($600 value)
- Company logo and description in the meeting program
- Logo of all sponsors on poster at meeting

"Tier II" Sponsorship / $3,750
- 1 registration
- 6-foot exhibit table
- Company logo and description in the meeting program
- Logo of all sponsors on poster at meeting
- Logo and description of company in JANNAF slideshow in each session
- Special thank you at keynote speech
- 1 guest ticket to networking night event ($45 value)

"Tier I" Sponsorship / $7,500
- 2 registrations
- 6-foot exhibit table
- Company logo and description in the meeting program
- Logo of all sponsors on poster at meeting
- Logo and description of company in JANNAF slideshow in each session
- Special thank you at keynote speech
- 2 guest tickets to networking night event ($90 value)
- Logo and description on sign in break room as sponsor
- Exclusive sponsorship of a mid-morning or mid-afternoon break, including signage throughout break room with company name and logo

*Exhibit space is limited and will be available on a first come, first served basis.

Exhibit Hours:

Monday: 10 a.m. - 5 p.m.
Tuesday - Thursday: 7 a.m. - 5 p.m.

Peak traffic hours:

7 a.m. - 8 a.m. (breakfast)
9:30 a.m. - 10:30 a.m. (break)
3 p.m. - 4 p.m. (break)

Set up and Breakdown:

Set up:
Sunday, 8 Dec, 4-6 p.m.
Monday, 9 Dec, 7-10 a.m.

Breakdown:
Thursday, 12 Dec, 4-6 p.m.

Sign up today!

For more information, to sponsor or exhibit, please contact Gabrielle Delisle, at 410-992-7300 x208 or GDelisle@erg.jhu.edu

https://www.jannaf.org/mtgs/2019Dec/pages/index.html