

JANNAF

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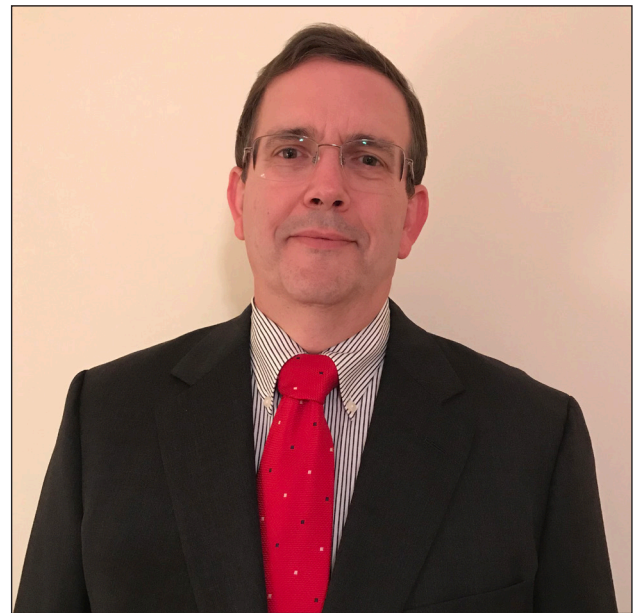


NEWS

Volume 9, Issue 1 Released September 1, 2020

Rescheduled Spring 2020 JANNAF Meeting to be Held Virtually

As a consequence of the global Covid-19 pandemic, the May 2020 JANNAF Meeting, originally scheduled from May 18-22 in Pittsburgh, Pa., will now take place in a virtual format from Sept. 29-Oct. 9, 2020. The featured keynote speaker at the meeting is Dr. Ronald M. Sega, Chief Technology Officer of the U.S. Army Futures Command. The Defense Information Systems Agency's Defense Collaboration Services (DCS) online platform will host all sessions of the meeting, which will feature a joint gathering of the 46th Structures and Mechanical Behavior (SMBS), 42nd Propellant and Explosives Development and Characterization (PEDCS), 33rd Rocket Nozzle Technology (RNTS), 31st Safety and Environmental Protection (SEPS), and 14th Modeling and Simulation (MSS) Subcommittees, as well as the 67th JANNAF Propulsion Meeting (JPM) and a meeting of the Programmatic and Industrial Base (PIB). The meeting



Paul J. Conroy, CCDC Army Research Laboratory, Aberdeen Proving Ground, Md., will chair the JANNAF Meeting.

will be chaired by Paul J. Conroy of the U.S. Army Combat Capabilities Development Center Army Research Laboratory in Aberdeen Proving Ground, Md.

(See Spring 2020 Virtual Meeting on page 3)

» Tampa JANNAF Meeting Review

PAGE 6

» In Memoriam

PAGE 9

» NPS Workshop

PAGE 14

» Women in the Propulsion Community

PAGE 18

» SPIRITS Software Update

PAGE 20



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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: 2019-0004
Meeting Proceedings of the 13th Modeling and Simulation (MSS) / 11th Liquid Propulsion (LPS) / and 10th Spacecraft Propulsion (SPS) Joint Subcommittee Meeting / and Programmatic and Industrial Base Meeting (Tampa, Florida)
Dec 2019
- 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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***JANNAF News is seeking short
(Dist A) technical articles for
future editions.***

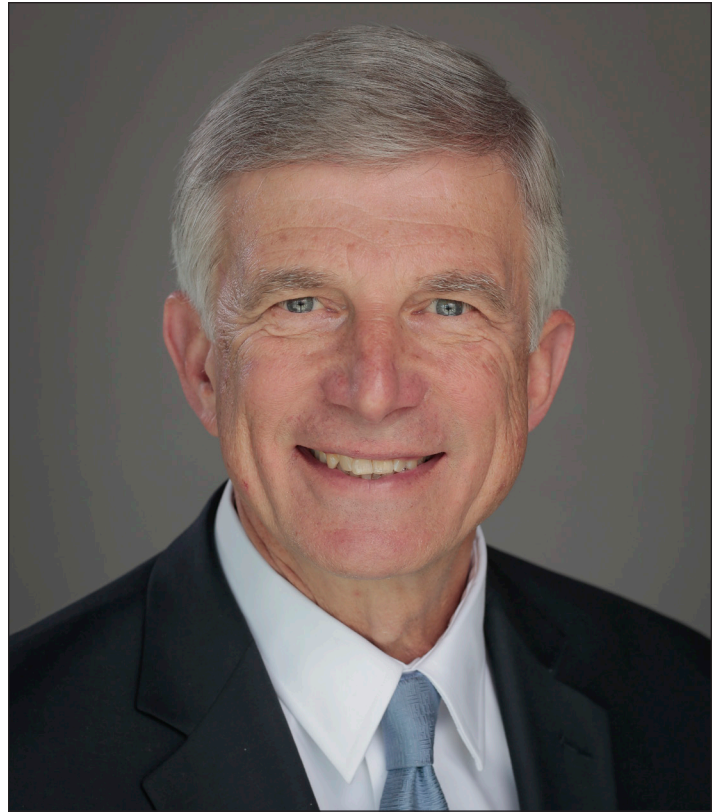
***If you are interested in submitting an article or
have any questions,
please contact
Managing Editor
Benjamin Schwantes at
bschwantes@erg.jhu.edu.***

Spring 2020 Virtual Meeting... *continued from page 1*

Dr. Sega's keynote speech, entitled "Thoughts on Propulsion Systems and Energetics – Past, Present and Future," will be held on Wednesday, Sept. 30. He will focus on the challenges that the JANNAF community faces at present, including 1) the high rate of change of technology in various areas across the globe, including advances in data science and production methods (e.g., artificial intelligence and additive manufacturing); 2) the increasing system complexities in and around propulsion and energetics products; and 3) the required speed in several dimensions that will impact the ability to be successful. His discussion will also include a look at the past to help frame a context for future opportunities and challenges and to the critical importance of talent for research and development leadership.

With a career spanning nearly 40 years, Dr. Ronald M. Sega has served in various roles from professor to astronaut and held prestigious leadership positions in government at the Department of Defense. He holds a Ph.D. from the University of Colorado, as well as a B.S. in Math and Physics from the U.S. Air Force Academy, and M.S. in Physics from the Ohio State University. Dr. Sega has been a professor and held many academic leadership positions for most of his career at both the University of Colorado at Colorado Springs, as well as at Colorado State University (CSU). Additionally, he served in the Air Force Reserve from 1982 until 2005, when he retired as a Major General and Command Pilot with more than 4,000 flying hours.

In addition to the 4,000 hours in military aviation; Dr. Sega also logged 420 hours in space as an astronaut for NASA. After joining NASA in 1990, he made his first shuttle flight in 1994 aboard the Space Shuttle Discovery. His second shuttle flight occurred in 1996 as a Payload Commander aboard Atlantis. During his time at NASA, he set several milestones for America and NASA. He was the first American to do EVA training in the Russian Hydrolab, as NASA's Director of Operations, Russia, where he was responsible for managing NASA activities and supporting astronaut and cosmonaut training for flights on the Russian Mir Space Station. He also served as Co-Principal Investigator and Program Manager for the Wake Field Facility, which



Ronald M. Sega, Ph.D., Chief Technology Officer, U.S. Army Futures Command, Austin, Texas, will be the keynote speaker at the virtual JANNAF Meeting.

was the primary payload on the Space Shuttle Discovery mission in 1994, a first for a member of NASA's Astronaut Corps.

Following his career as an astronaut, Dr. Sega moved into leadership positions at the DoD, where he was appointed Director of Defense Research and Engineering, Office of the Secretary of Defense, in 2001. During this time, he was the Chief Technology Officer for the Department and the chief adviser to the Secretary of Defense and Under Secretary of Defense for Acquisition, Technology and Logistics for scientific and technical matters.

From 2005 to 2007, he was the Under Secretary of the Air Force, Washington, D.C. In this role, he was responsible for all actions of the Air Force on behalf of the Secretary of the Air Force, and was Acting Secretary in the Secretary's absence.

For complete details on all the papers and topics at the rescheduled May 2020 JANNAF Meeting, please see the meeting program, which is available through the JANNAF portal at <https://www.jannaf.org/mtgs/2020Sept/pages/index.html>.

Rescheduled Spring 2020 Meeting Subcommittee Highlights

SMBS

The JANNAF 46th Structures and Mechanical Behavior Subcommittee (SMBS) sessions will present work on advances in damage tolerance, non-destructive evaluation, materials properties and characterization, and structural analysis and design. A joint session with the Modeling and Simulation Subcommittee (MSS) will focus on Chemistry in Service Life Estimates. JANNAF SMBS Panels will meet to discuss current and future needs in research in the areas within the scope of the subcommittee, and areas of joint participation between Rocket Nozzle Technology Subcommittee (RNTS) and MSS.

SEPS

The JANNAF 31st Safety and Environmental Protection Subcommittee (SEPS) meeting sessions will address issues related to the safety, health, and environmental impacts associated with the manufacture, use, storage, and demilitarization of propellants, explosives, and pyrotechnics. Technical sessions will address the synthesis and use of environmentally friendly energetics; health effects of novel energetic compounds, precursors, and combustion products; and novel energetic processing and demilitarization techniques. In keeping with trends in propellant development, SEPS will also be addressing the safety of liquid natural gas/liquid oxygen (LNG/LOX) propellants in support of the current National Space initiative, as well as teaming up with PEDCS to present current and emerging technologies in green energetics. SEPS welcomes Jeanne Hartzell, Ph.D., Naval Ordnance Safety and Security Activity, Indian Head, Md., as the newly appointed Mission Area IV Environmental Co-Chair, and LCDR N. Cody Schaal, Naval Medical Research Unit, Wright-Patterson AFB, as the newly appointed Mission Area V Industrial Hygiene Co-Chair.

RNTS

The JANNAF 33rd Rocket Nozzle Technology Subcommittee (RNTS) will provide a forum for promoting technical exchange and addressing problems associated with the application of advanced composite materials, including carbon-carbon, ceramic matrix, and carbon phenolic composites, and other advanced materials, as applied to solid rocket nozzles and their components; nozzle-based propulsion control systems; and related technology developments for liquid and electric propulsion. RNTS will hold two sessions, a joint session focusing on Nozzle Thermal, Structural, and Fluids Analysis and Modeling, and a second session on Nozzle Material Development. A Panel Session on Nozzle Analysis and Modeling will collect attendees' thoughts on future needs in the RNTS area of interest, as there is a need to reenergize this technical field.

PEDCS

The JANNAF 42nd Propellant and Explosives Development and Characterization Subcommittee (PEDCS) meeting will offer a forum for participants to share emerging research and advancements in the technologies required to develop, manufacture, and characterize energetic formulations used in the development, manufacture, performance, and operation of weapon systems, propulsion systems, and gas generator devices. PEDCS will once again join with the Safety and Environmental Subcommittee (SEPS) to hold a Panel Session to address developments in green energetic ingredients, formulations, and processing technologies that permit enhanced recycling, recovery, reuse, and waste reduction during manufacturing, testing, operating, and demilitarizing energetic systems. The PEDCS Technical Steering Group (TSG) is excited to welcome Phillip J. Samuels, CCDC Armaments Center, Picatinny Arsenal, to his role as the PEDCS Mission Area I Liquid Propellants Chair, and Adam J. Brand, Air Force Research Laboratory, Edwards AFB, as the newest TSG member.

MSS

The JANNAF 14th Modeling and Simulation Subcommittee (MSS) meeting will have sessions on the following:

- Nondestructive evaluation
- Service life monitoring and motor aging, as well as chemical modeling
- Code demonstrations on FEM (Finite Element Model) Builder and HERO (Heat transfer and EROsion Analysis Program)
- Nozzle thermal, structural, and fluids analysis and modeling
- Uncertainty quantification
- Advances in modeling and simulation

This will be the first time that MSS will meet with RNTS, SMBS, PEDCS, and SEPS due to the new meeting rotation schedule for MSS. MSS is very excited for the opportunity and the sessions it hosts will reflect the collaboration that is possible between these subcommittees. All but one of its regular sessions are joint sessions with either SMBS or RNTS. These mostly involve nondestructive evaluation and motor aging modeling techniques along with nozzle analysis.

MSS will also be holding a plenary session. Invited speaker Lee Davis, Ph.D., Northrop Grumman, Brigham City, Utah, will not be able to attend, but R. Scott Hyde, Northrop Grumman, Brigham City, Utah, will share Dr Lee's insights on the evolution of propellant modeling from statistics- to physics-based models. Dr. Davis is a world leader in solid propellant chemistry, and MSS is very happy to have his insights on the topic.

MSS will also be holding a code demonstration, as it has at past JANNAF Meetings. FEM Builder and HERO will be demonstrated for the JANNAF community. The session will provide participants with a basic understanding of how to apply these modeling tools to their own work. The code demonstrations have been extremely popular in the past, and MSS is pleased to have the opportunity to demonstrate these tools to a relevant user community.

JANNAF FAQ: How to Access JANNAF Journal Articles and JANNAF Meeting Proceedings through JDOC

How can I access the JANNAF Journal and JANNAF Meeting Proceedings electronically?

- JANNAF Journal articles and JANNAF Meeting Proceedings may be accessed through JDOC (the JANNAF Digital Online Collection) on the JANNAF website (www.jannaf.org). You must have an active JANNAF Secure Portal Account in order to log into the JANNAF website and access JDOC. You may register for a JANNAF Secure Portal Account on the JANNAF front page by following the "Create new account" link. If your account has expired, please contact Tricia Frey, ERG Assistant Facility Security Officer (tfrey@erg.jhu.edu).

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How can I search for specific JANNAF Journal articles or JANNAF Meeting Proceedings on JDOC?

- Open JDOC and then click on the Search tab. You may search by abstract number, author, title, keyword, or various other modifiers. Type your query into the search field and hit the search button. For JANNAF Journal articles, type "JANNAF Journal" in quotations, in addition to the search term, in order to narrow down the search to just JANNAF Journal articles.

Future Missions to Moon Discussed at Tampa JANNAF

The JANNAF community gathered in sunny Tampa, Fla., in December 2019 for 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). Hani Kamhawi, Ph.D., from NASA Glenn Research Center, chaired the five-day meeting. Marshall Smith, Director of the Human Lunar Exploration program at NASA Headquarters, delivered the keynote speech about the need and strategy for more long-term exploration on the Moon, before venturing to Mars.

Smith focused on the future of human spaceflight over the next decade, describing the Artemis program, which is scheduled to return Americans to the Moon by 2024. The crew will include the first woman to step on the lunar surface. The first Artemis mission will be uncrewed in order to do a full test of the Space Launch System and Orion System, before sending humans on the subsequent missions.

“We’re really going to test the system out and stress the system in ways that we haven’t done before,” Smith said.

Through commercial and international partnerships, NASA plans to establish a Lunar Gateway in a near-rectilinear halo orbit that will provide access to the lunar surface while avoiding communication blackouts with the Earth, allowing for longer-duration human habitation. The Lunar Gateway will consist of a Power-Propulsion Element (PPE) and a Habitation and Logistics Outpost (HALO) for the crew. The HALO will also provide docking for the Orion spacecraft and a lunar lander. Accessing the Moon via the Lunar Gateway will help to economize on the energy required to reach lunar orbit from low-Earth orbit (LEO) and permit more mass to be transported by spacecraft. Smith argued that lunar missions, initially short term and eventually long



Keynote speaker Marshall Smith, Director of Human Lunar Exploration Program, NASA Headquarters, Washington, D.C..

term, will be valuable from both a strategic and scientific perspective. They will help to establish a sustainable U.S. presence on the Moon, providing an opportunity to develop technologies that may later be employed for a two-to-three-year mission to Mars, and offer new insights about lunar geology in areas previously unexplored by the Apollo program.

“We’re actually interested more in the South Pole of the Moon. The South Pole is where we are going to go first,” Smith stated. “With Apollo 17, we’ve covered about the geographic equivalent of the state of Michigan. To say you understand the whole of the Earth, because you’ve been to Michigan is not really viable. So there’s a whole lot more about the Moon that we really do need to explore and understand.”

In addition to undiscovered information on the surface of the Moon, there may even be important resources.

“What we want to do in the future is explore the distribution of resources,” Smith said. “The Moon is really no different than it was 3.6 billion years ago. It hasn’t changed. And so, there’s things we don’t really have access to on Earth that have been turned over through the billions of years, that are just sitting on the surface of the Moon. And we want to go and understand that.”

Highlighting the CLPS program, also known as Commercial Lunar Payload Services, Smith promoted the importance of working with commercial partners, both to develop the necessary hardware for the lunar program, and to facilitate unmanned lunar exploration and logistical support. Through the program, commer-



Steven F. Son, Ph.D., Purdue University, West Lafayette, Ind., thanks JANNAF participants who contributed to the production of Volumes 1–10 of the JANNAF Journal of Propulsion and Energetics.

cial providers will eventually deliver robotic rovers and cargo landers to the lunar surface. Smith argued that specific work remains to permit long-term human habitation of the Moon and eventual Mars exploration. Improvements in communication, particularly laser-based communication, will ensure effective interplanetary voice and data transmission, and perfecting the autonomous docking and assembly systems will enable construction of the Lunar Gateway. Surface mobility systems, including space suits and rovers, require additional development and testing as well.

Smith also stressed the importance of more research on the long-term impact of deep-space exploration on human biology, which will be critical to ensure the safety of astronauts. He is encouraged that some of this research and development is already in progress and that new in-

ternational standards for space technology, such as life support and rendezvous and docking systems, are being put into place. He concluded by emphasizing the value of lunar and Martian exploration for the United States and for humankind in general and noted that NASA has the capacity, purpose, charge, and determination to make such programs happen in the next decade or so.

Following Smith's keynote address, Christine Michienzi, Ph.D., and Thomas M. Brown, Ph.D., co-chairs of the Programmatic and Industrial Base (PIB) Executive Committee (PEC), discussed the Committee's role within JANNAF and encouraged the community to participate in PIB activities. Michienzi introduced Brown as the new NASA co-chair of the PIB. Brown spoke briefly about PIB activities involving methane and liquid natural gas propellants for space launch and the creation of a rocket reusability panel.



Alan Sutton, AFRL, accepts a Liquid Propulsion Subcommittee Outstanding Achievement Award from Daniel L. Brown, Ph.D., AFRL, on behalf of a research team from AFRL, Aerojet Rocketdyne, the Air Force Space and Missile Systems Center, the Aerospace Corporation, Sierra Lobo, Inc., NASA Stennis Space Center, and NASA MSFC. The award recognized the team's successful completion of the Hydrocarbon Boost (HCB) preburner test campaign.



Robert Jensen, Ph.D., Sierra Lobo, Inc., accepts a Liquid Propulsion Subcommittee Lifetime Achievement Award from Daniel L. Brown, Ph.D., AFRL, on behalf of Douglas G. Talley, Ph.D., AFRL.

Meeting attendees celebrated the publication of the 10th volume of the *JANNAF Journal of Propulsion and Energetics* at the meeting, with cake and ice cream at the Tuesday afternoon coffee break. During the awards ceremony, Steven F. Son, Ph.D., the *Journal's* Editor-in-Chief, thanked all of the contributors to each of the volumes published over the past decade.

"That's taken a lot of effort by a lot of people. It's taken more than 450 participants," Son noted. "That includes authors, reviewers, associate editors, and so forth. It's taken us about a decade to reach this point as well."

(See December 2019 JANNAF Meeting on page 8)

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

Son also noted that review times for manuscripts had been reduced and that electronic prepublication of manuscripts via JDOC (the JANNAF Digital Online Collection) on the JANNAF website would make re-



Darren Tinker, Vanderbilt University, accepts the JANNAF Best Student Paper Award from Meeting Chair Hani Kamhawi, Ph.D., NASA Glenn Research Center, for a paper entitled, "Computational Verification of Design Analytics for an LRE Augmented Spark Impinging Pentad Igniter." Tinker's coauthors included Brian R. Richardson, Ph.D., NASA MSFC; Robin J. Osborne, ERC Incorporated, Jacobs Space Exploration Group; Robert W. Pitz, Ph.D., Vanderbilt University; and Jeffrey S. West, Ph.D., NASA MSFC.

search available to the community much more expeditiously than in previous years. There are currently four *JANNAF Journal* articles available in JDOC. These individual articles were published online, ahead of the publication of the full Volume 11 of the *Journal*, which is scheduled for December 2020.

During the awards ceremony, LPS co-chair Daniel L. Brown, Ph.D., Air Force Research Laboratory (AFRL), presented two awards on behalf of the LPS. The first, a Lifetime Achievement Award, went to Douglas G. Talley, Ph.D., AFRL, for leading innovative research into liquid rocket engine physics for more than 30 years. Robert Jensen, Ph.D., Sierra Lobo, Inc., accepted the award on Talley's behalf. The second award, an Outstanding Achievement Award, went to a team of researchers from AFRL, Aerojet Rocketdyne, the Air Force Space and Missile Systems Center, the Aerospace Corporation, Sierra Lobo, Inc., NASA Stennis Space Center, and NASA MSFC for successfully completing the Hydrocarbon Boost

(HCB) preburner test campaign. The test program focused on improving scientific and technical understanding of oxygen-rich, staged combustion through more than 21 hot fire tests. The preburner achieved the highest operating pressure for a U.S. kerosene-based combustor, and met all other objectives of the test. Alan Sutton, AFRL, accepted the award on behalf of the research team.

The final award presented at the Tampa JANNAF Meeting went to the best student paper. Darren Tinker, from Vanderbilt University, received the award for a paper entitled, "Computational Verification of Design Analytics for an LRE Augmented Spark Impinging Pentad Igniter." Tinker's coauthors included Brian R. Richardson, Ph.D., NASA MSFC, Robin J. Osborne, ERC Incorporated, Jacobs Space Exploration Group, Robert W. Pitz, Ph.D., also from Vanderbilt University, and Jeffrey S. West, Ph.D., NASA MSFC.



Programmatic and Industrial Base Executive Committee (PEC) Co-chair Christine Michienzi, Ph.D., (right) introduces the new PEC Co-Chair Thomas M. Brown, Ph.D., NASA MSFC.

On Friday, JHU ERG representative Nick Keim presented an overview of JANNAF's technical services to its members. The seminar was intended to remind attendees that JANNAF is more than a conference and reinvigorate the spirit of collaboration beyond the meetings. JANNAF services include Technical and Bibliographic Inquiries; the JANNAF Portal; JANNAF Databases; JANNAF Codes; and Workshops.

In Memoriam

Edmond Kin Sing “Ed” Liu, Ph.D., former director of the Chemical Propulsion Information Analysis Center (CPIAC) – now known as the Energetics Research Group (ERG) – and a longtime JANNAF member, passed away on March 26, 2020, at the age of 68. Dr. Liu was born on June 7, 1951, in Honolulu, Hawaii, to Young Wah and Shuk Kwan Liu. After graduating from McKinley High School in Honolulu, Liu attended the University of Chicago, where he earned a B.S. in chemistry in 1973. Upon completing his undergraduate studies, Liu went on to earn a Ph.D. in inorganic chemistry from the Massachusetts Institute of Technology in 1977. He then received a postdoctoral research appointment at Los Alamos National Laboratory from 1978 to 1979. Liu joined Aerojet (now Aerojet Rocketdyne) following the completion of his postdoc. He served as a Chemistry Specialist and Chemistry Manager for various NASA and Department of Defense solid propellant and energetic materials-related programs at Aerojet, and later as a Technical Principal in Energetic Materials Chemistry, Engineering, and Technology. As Technical Principal, Liu led an Integrated Product Team that shepherded new energetic materials from the laboratory research phase through pilot plant operations and commercialization. After spending 26 years at Aerojet, Liu joined CPIAC in 2006 as Director and served ably in that capacity until 2013 when he transitioned to work at the Johns Hopkins University Applied Physics Laboratory.

During his years at Aerojet and CPIAC, Liu was closely involved with JANNAF. He authored many papers for the Combustion (CS), Propellant & Explosives Development and Characterization (PEDCS), and Structures & Mechanical Behavior (SMBS) Subcommittees on a variety of topics related to the characterization, behavior, and surveillance of energetic materials. Liu also served as a session chairman on many occasions and as industry chairman for the SMBS Service Life Panel from 1995 to 2003. Liu also published articles in various academic journals



Edmund K.S. “Ed” Liu, Ph.D. (1951-2020)

and belonged to a number of professional societies including the American Chemical Society, American Institute of Aeronautics and Astronautics, National Defense Industrial Association, and Sigma XI.

In his free time, Liu enjoyed traveling, gardening, and fishing. He visited Alaska annually for fishing trips with his brother, Raymond. Liu is survived by his wife of 39 years, Edwina; daughters Jennifer and Katherine; mother Shuk Kwan; and siblings Gladys and Edward. He is predeceased by his father, Young Wah, and brother Raymond.

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.

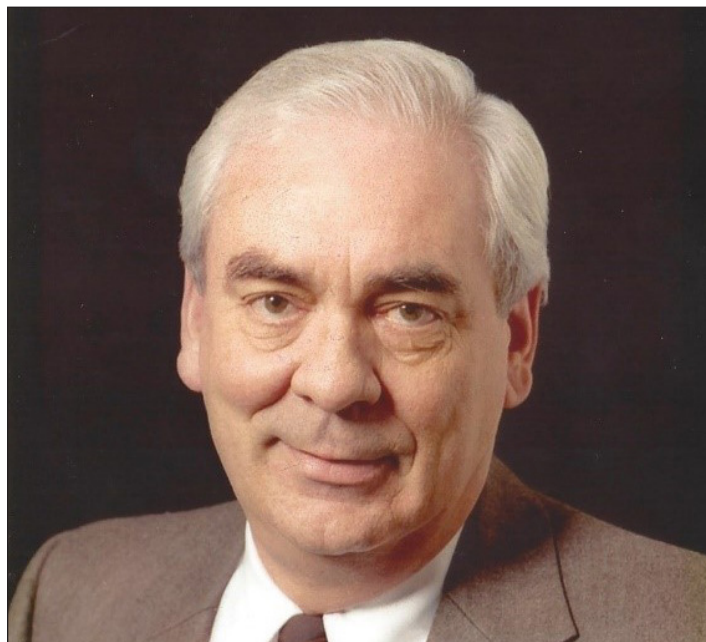
In Memoriam

David Addison Flanigan, Ph.D., passed away on June 21, 2019. Dr. Flanigan was born on February 14, 1936, in Columbus, Ind., to Leola Irene Fogle Flanigan and Addison Andrew Flanigan. He spent his earliest years in Chicago where his dad took him to his first Cubs game at Wrigley Field at the age of five. A lifelong love affair was born that day, which for Dave meant decades of heartbreak and then one perfect moment when his Cubbies won the World Series in 2016, and he cried tears of joy.

Flanigan graduated from high school in Mitchell, Ind., at the age of 16, attended Rose Polytechnic Institute in Terre Haute, Ind., and completed his undergraduate degree from Western Kentucky University. He went on to earn his Ph.D. in analytical chemistry from Vanderbilt University in 1962. He was hired by Thiokol Corporation (now Northrop Grumman Innovation Systems (NGIS)) that same year and spent his entire career with the company, first in Huntsville, Ala.; then Chicago, and finally Utah, retiring as their Director of Advanced Technology in 1999. There is so much that could be written about his career but what he was most proud of were the three generations of talented young chemists that he was able to mentor along the way, many of whom came from across the country to visit with him in his final days.

Flanigan mentored numerous scientists and engineers throughout his career and aided many with his insights and critical thinking. He always challenged researchers to “do the critical experiment” and to strive for excellence. He was an excellent communicator and motivator. He introduced many colorful sayings into the propulsion lexicon. A favorite for many: “ducks migrate, plasticizers diffuse.”

Flanigan pioneered Thiokol’s University Independent Research and Development program, which funded research at several U.S. universities – and yielded several prominent engineers and scientists, some of whom are still working at what is now Northrop Grumman.



David A. Flanigan, Ph.D. (1936-2019)

His research over the years focused on nitramine, ammonium perchlorate, and boron combustion as well as propellant development. He was instrumental (through a great partnership with Robert Askins) in Thiokol’s development of its TOW and Hellfire Minimum Signature production propellants. He authored and co-authored many JANNAF articles and reports and was very active in the Combustion Subcommittee’s (CS) activities..

After retirement, Flanigan continued to mentor and technically guide as a member of the Independent Advisory Committee for the Office of the Secretary of Defense Joint Insensitive Munitions Technology Program (JIMTP). He also served admirably on the investigative committee for the Army at Redstone Arsenal after the explosion on May 5 2010 that killed two men. His daily mantra was that “we owe it to these two men to determine the root cause.”

He met his wife Yvonne Keel Flanigan (who also worked at Thiokol) in coastal Georgia in the late 1960's and they were together for 51 years, sharing a room at the nursing home and passing within 26 hours of one another.

Dr. Flanigan traveled the world with his job but his favorite place was at home, working out in his yard. Upon his retirement in Athens, Ala., he discovered day-

(See Flanigan Obituary on page 15)

In Memoriam

The JANNAF community is deeply saddened to learn of the passing of Michael S. Holden, Ph.D., CUBRC Aerosciences Group, Buffalo, N.Y., on December 8, 2019, at the age of 81. Holden passed away due to injuries sustained while skiing, a hobby he greatly enjoyed along with tennis. An aerospace engineer by training, Holden served as Vice President of CUBRC's Aerosciences Group at the time of his death. He was a leader in the field of supersonic and hypersonic research and deeply involved in the design, construction, and operation of ground test facilities for hypersonic craft. He played a key role in the development of CUBRC's Large Energy National Shocktunnel (LENS) test facility and subsequent test facilities and was recognized by fellow researchers in government, industry, and academia for his accomplishments by being selected as an American Institute of Aeronautics and Astronautics Fellow. Holden authored and coauthored numerous papers involving hypersonic combustion, shock, boundary layers, and other matters related to hypervelocity,



Michael S. Holden (1938-2019)

as well as hypersonic wind tunnel design, for JANNAF Meetings over more than two decades and was active in the Airbreathing Propulsion and Combustion Subcommittees. Holden is survived by his wife, Susan; his sister, Anne Collins; his children, Michelle Holden and Beth Anne Kempner; and his grandson, Teddy.

AFRL-Led Scramjet Development Team Receives Prestigious Aviation Week Award

A team from the Air Force Research Laboratory (AFRL) working with the Arnold Engineering Development Center at Arnold Air Force Base, Tenn., recently learned that they had received a prestigious Laureate Award from Aviation Week Networks for work involving the Medium Scale Critical Components (MSCC) scramjet engine. The Annual Aviation Week Laureate Awards recognize extraordinary achievements of individuals and teams in aerospace. The MSCC team, whose AFRL members included Todd F. Barhorst, Jeffrey M. Donbar, Ph.D., Paul Kennedy, Christopher G. Murawski, Ph.D., Lt. Samuel Nyamekye, and Kristin Rice, Ph.D., working in conjunction with Northrop Grumman, was honored in



Aviation Week Networks Laureate Awards from prior ceremony at the National Building Museum, Washington, D.C. Photo courtesy Aviation Week Networks.

the Defense-Propulsion category for setting a record for thrust produced by a U.S. air-breathing hypersonic engine. The JANNAF community congratulates the award-winning team for its accomplishments.

Tampa Meeting Subcommittee Review

MSS

The 13th Modeling and Simulation Subcommittee (MSS) joined the Spacecraft Propulsion Subcommittee (SPS) and the Liquid Propulsion Subcommittee (LPS) for the Tampa JANNAF Meeting. MSS addressed the following topics through a full week of well-attended regular sessions, workshops, and specialist sessions:

- Rotating detonation rocket engines (RDREs) ideal performance metrics, technology maturation, and sharing
- Digital engineering, specifically related to statistical modeling
- Model verification, validation, and uncertainty quantification
- Nonlinear slosh dampening

The workshop involving RDREs focused on shifting RDRE technology away from the modeling stage to technology maturation, including instrumentation, testing, and advancing current Small Business Innovation Research topics to their next phases. Due to technology progression, RDREs will now fall under the oversight of LPS instead of MSS. However, work remains to be done on quantifying the ideal performance metrics for RDREs.

Digital engineering focused heavily on statistical modeling and systems modeling and analysis. Most of the work presented involved system autonomy or engine analysis. In addition, MSS hosted a code demonstration featuring KESTRAL and discussed the possibility of forming a user group for the propulsion modeling code.

Following the Tampa JANNAF Meeting, Adrian Bolt, CCDC Picatinny Arsenal, joined the MSS Technical Steering Group (TSG). Bolt rounds out Army representation on the TSG. He will contribute new and vibrant ideas as MSS moves forward and we look forward to having him onboard!

LPS

The 11th Liquid Propulsion Subcommittee (LPS) hosted over 80 presentations spread across 13 technical sessions, which covered a range of topics currently affecting liquid propulsion research, including combustion stability, rotating detonation engines, advanced materials, and hydrocarbon fuels research. Highlights included a plenary panel session entitled “U.S. Small Launch Industry Perspectives on Future Liquid Rocket Engine Development.” Panel members included Harrison F. O’Hanley, ABL Space Systems, El Segundo, Calif.; Philip C. Pelfry, P3 Technologies, LLC, Jupiter, Fla.; and Adam G. Harris, Interstellar Technologies, LLC, Huntsville, Ala. N. Wayne Hale, Special Aerospace Services, LLC, Boulder Co., and the former manager of NASA’s Space Shuttle Program, served as the moderator. The panel covered a range of topics, including funding sources for new industry launch providers, novel launch and engine technologies, and perspectives on the state of the launch industry moving forward as the number of small launch service providers continues to grow.

Technical presentations at the meeting covered a wide range of traditional subjects, such as combustion stability, as well as novel topics like additive manufacturing. Of particular note, LPS hosted a workshop to gauge community interest in forming a panel to study Rotating Detonation Engine (RDE) technologies with NASA and Air Force Research Laboratory collaboration, in addition to several presentations covering novel RDE technologies and research. Other areas of technical interest included methane-fueled liquid rocket engines combustion models, cryotank technologies, additive manufacturing of liquid rocket engine components, and aerospike engine development.

SPS

The 10th Spacecraft Propulsion Subcommittee (SPS) held a full week of regular sessions, workshops, and specialist sessions. The main topics addressed by the subcommittee included:

- Electric propulsion developments, including Hall Effect thrusters
- Micropropulsion and multimode propulsion
- Green propellant characterization and behavior
- Advancements in nuclear thermal propulsion

All sessions were well attended. The electric propulsion community is incredibly active and continues to make rapid progress with their work. Participants discussed new flight systems and diagnostics with respect to current and future programs. A two-part workshop provided updates on the status of the EPOSE IV (Electric Propulsion in the Space Environment and Facility Interactions IV) program.

Micropropulsion for cubesats was a significant topic of discussion, particularly since the SPS community is currently formulating new guidelines for assigning Technology Readiness Levels (TRLs) to cubesat propulsion elements. Discussions included which performance metrics would be adequate to describe flight hardware for launch. This is particularly relevant since there are many different types of missions proposed for cubesats. These could include launches to low-Earth orbit (LEO), geosynchronous-equatorial orbit, the Moon, Mars, or even to the Sun. Each of these missions would require vastly different propulsion technologies. A cubesat that will operate in LEO for a few months does not need the same rigor in design and testing prior to launch as, say, a flagship mission to Mars. Work continues on the TRL guidelines and they will soon be released to the JANNAF community.

There was increased interest in nuclear thermal propulsion (NTP) at the Tampa JANNAF Meeting. A plenary panel discussed recent developments in NTP as well as challenges moving forward with the technology for spacecraft propulsion applications. Representa-

JANNAF Journal Electronic Prepublication Program Live!

The *JANNAF Journal of Propulsion and Energetics* is happy to announce that its new electronic prepublication program is now live. This program allows authors and readers to access articles much sooner than when the full volume is published annually. Publication-ready articles will be available electronically via JDOC, the JANNAF Digital Online Collection, as soon as they have been accepted for publication, edited, and approved by the author(s). Articles published electronically will still be available in print in the annual *JANNAF Journal* volume released each December. Five electronic prepublication articles are currently available and may be accessed via JDOC by searching for Abstract Numbers 2020-0001A through 2020-0001E. Future electronic prepublication articles will be announced via the news section on the front page of the JANNAF website.

tatives from BWX Technologies, Aerojet Rocketdyne, NASA, and the Institute for Defense Analysis participated on the panel. In addition to the panel discussion, an entire regular session was devoted to NTP. Fuel advancements, reactor designs, and mission requirements were among the topics addressed by presenters.

An SPS Technical Steering Group (TSG) membership change was also announced at the Tampa JANNAF Meeting. Eric Cardiff, Ph.D., NASA Goddard Space Flight Center (GSFC), will be joining the TSG. Dr. Cardiff's experience at NASA GSFC will continue to round out NASA's representation on the TSG. Looking forward, however, SPS is seeking Army representatives to join the TSG, as open spots are currently available.

SPS Hosts Space-Based Nuclear Power Workshop

Since the early years of manned space flight, space-based nuclear power has been a topic of interest and concern to the spaceflight community. The January 2020 JANNAF Space-Based Energy Workshop on State-of-the-Art Nuclear Power Systems (NPS) organized by the Spacecraft Propulsion Subcommittee aimed to differentiate past attempts to develop space-based nuclear power technologies with current government and industry efforts and to establish a clear, efficient, and achievable path forward for launching a fission-based space power system. Moderated by N. Wayne Hale, Special Aerospace Services, LLC, Boulder, Co., and the former manager of NASA's Space Shuttle Program, the workshop included government participants from various agencies including NASA, the Department of Energy (DoE), the National Nuclear Security Administration, and the National Laboratories; industry participants from companies such as Interstellar Technologies, LLC, Aerojet Rocketdyne, and BWX Technologies, Inc.; and academic participants from Johns Hopkins University.

The United States has reserved space-based nuclear power systems for flagship exploration missions

launched to the Moon, Mars, and the outer planets of the Solar System. However, these missions have employed radioisotope thermoelectric power generation systems rather than fission-based power generation systems similar to those found in terrestrial nuclear reactors. With new missions to the Moon expected in the next decade, and missions to Mars anticipated in the not-too-distant future, space-based nuclear power will prove to be a critical enabling technology and provide a paradigm shift in how future missions obtain energy for both spacecraft propulsion and surface-based power generation purposes.

NASA's current nuclear thermal propulsion project and the joint NASA/DoE Kilopower project serve as initial steps toward developing the necessary technologies for space-based nuclear power systems. Other prominent players in the field include DARPA (Defense Advanced Research Projects Agency) and the Department of Defense, as well as various industry participants. The NPS Workshop offered an important venue for key personnel involved with all aspects of these current projects to discuss technical barriers, establish agreements within the community, and lay a clear path forward for launching a nuclear power system.

50th CS / 38th APS / 38th EPSS / 32nd ESHS / JPM / PIB

December 7-17, 2020

Virtual Meeting

Questions

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

- CS – Ben Hill-Lam (bhill-lam@erg.jhu.edu / 443-718-5011)
- APS – Alex Bishop (abishop@erg.jhu.edu / 443-718-5008)
- EPSS – Nicholas Keim (nkeim@erg.jhu.edu / 443-718-5005)
- ESHS – William Bagley (wbagley@erg.jhu.edu / 443-718-5009)
- JPM – Nicholas Keim (nkeim@erg.jhu.edu / 443-718-5005)
- PIB – Kirk Sharp (ksharp@erg.jhu.edu / 228-234-5423)

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

Based on discussions at the workshop, the technical experts present reached the following conclusions:

- Highly enriched uranium should not be precluded as a power source in future space-based reactors.
- The new nuclear launch approval process is agreeable due to the fact that it is not prescriptive but risk-based.
- Two near-term flight demonstrations of nuclear systems are necessary: one for power and one for propulsion.
- A tiered approach should be adopted for test facility development for nuclear power and propulsion.
- Moderator and fuel development is critical for fission systems.
- Continual lack of action is detrimental to the United States and its national security.

Workshop participants argued that even though surface power generation and spacecraft propulsion are inherently related, each technology should have its own complementary technology development roadmap. For nuclear thermal propulsion, the experts recommended the following strategy:

- Perform a tiered approach to nuclear fuels testing that evolves into establishing a national test capability to study and verify separate effects and models of reactor systems.
- Develop a flight demonstration system accord-

ing to NASA requirements of 900 seconds of specific impulse.

For nuclear power generation, workshop participants deemed three main steps to be necessary for successful technology development:

- From the design of the KRUSTY (Kilopower Reactor Using Sterling Technology) reactor, create a 1-kW demonstration reactor to be placed into cis-lunar space.
- During verification of the flight demonstration, develop a 10-kW reactor based on the same design to provide power on the lunar surface or for nuclear electric propulsion (whichever is more desirable at the time).
- Design and create a 10-kW nuclear electric propulsion spacecraft for deep space exploration.

The first step of the nuclear thermal propulsion roadmap will greatly advance U.S. ground-based testing capabilities for nuclear reactors. Likewise, the first two steps of the nuclear power generation roadmap will advance the development of space-based nuclear power systems. With both roadmaps offering benefits to each community, workshop participants hoped that real progress would be made in developing and launching nuclear power systems in the near future. They also appreciated the opportunity to represent their respective organizations and discuss their areas of expertise with fellow subject matter experts. It is hoped that future workshops will continue the work of developing a space-based nuclear power system for American spaceflight.

Flanigan Obituary... *continued from page 10*

lilies and spent countless hours transforming a bare backyard into a floral wonderland, with over 800 varieties of daylilies on display, including one that was named for him by its hybridizer - "Dr. Dave." He was also co-founder and several-time President of the North Alabama Daylily Society.

Dave loved his Cubs, the Vanderbilt Commodores, and anyone who beat Tennessee at any time. He attend-

ed the first Super Bowl. He and his partner were National Sports Car Rally Champions in the late 1970's. His daughter and son-in-law scattered his ashes at Wrigley Field, Vanderbilt University, his childhood homesite, Western KY University, and on his parent's graves.

Dr. Flanigan leaves behind a brother, two sons, a daughter, and seven grandchildren.

Courtesy of Dr. Jamie B. Neidert

ERG Technical Staff Supports Subcommittees

ERG's technical staff is comprised of three engineers and a former bomb technician who all work on research and support of chemical propulsion and energetics.



ERG Deputy Director Nick Keim

ing meetings, as well as researching JANANF's historical databases for technical inquiries on rocket propulsion from the JANNAF community.

Nick Keim, the deputy director of ERG, manages the technical team as well as the AERoFuels Laboratory, ERG's facility for testing rocket fuels. It was established in 2012 in collaboration with the Joint Army-Navy-NASA-Air Force Liquid Propulsion Subcommittee Hydrocarbon Fuels Panel for the research and development of hydrocarbon fuels for advanced

airbreathing and rocket engines. Keim also supports the Exhaust Plume and Signatures Subcommittee and the Commodities Panel for



ERG Associate Research Engineer Alex Bishop

JANNAF's Programmatic and Industrial Base (PIB).

Alex Bishop and Ben Hill-Lam both split their time between running rocket fuel experiments in the

AERoFuels Lab, conducting technical inquiries using the JANNAF databases and ERG's library of rocket

propulsion data, as well as supporting various JANNAF subcommittees. Bishop represents ERG for the Airbreathing Propulsion Subcommittee, Modeling and Simulation Subcommittee, and Spacecraft Propulsion Subcommittee. Hill-Lam supports



ERG Associate Research Engineer William A. Bagley

the Combustion Subcommittee and the Liquid Propulsion Subcommittee.

William Bagley supports the Propellant and Explosives Development and Characterization Subcommittee, the Energetic Systems Hazards Subcommittee, and the Safety and

Environmental Protection Subcommittee. Bagley's expertise is in explosives and he supports various projects for ERG and Johns Hopkins University in this area.

ERG also has several employees that work part-time remotely to support JANNAF. You may have seen Bryan DeHoff and Kirk Sharp at ERG meetings. DeHoff supports the Rocket Nozzle Technology Subcommittee and the Structures and Mechanical Behavior Subcommittee, while Sharp provides facilitation support to all areas of the PIB program.



ERG Associate Research Engineer Ben Hill-Lam

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Material in the JANNAF Secure Portal is unclassified but restricted from release to the public domain by Department of Defense Directive (DODD) 5230.25, “Withholding of Unclassified Technical Data from Public Disclosure.” Portal users should not share login details or passwords with others. Any information printed from JDOC or another secure JANNAF database, as well as the Small Teams Portal, should not be shared with anyone outside the user’s organization without specific permission from the ERG Security Team. The information below is intended for internal company use only and will help you better understand your responsibilities when accessing material in the JANNAF Secure Portal.

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

“Computational Verification of Design Analytics for an LRE Augmented Spark Impinging Pentad Igniter”

Student/Primary Author:

Darren C. Tinker, Vanderbilt University

Authors:

Darren C. Tinker, Vanderbilt University

Brian R. Richardson, NASA Marshall Space Flight Center

Robin J. Osborne, ERC Incorporated, Jacobs Space Exploration Group

Robert W. Pitz, Vanderbilt University

Jeffrey S. West, NASA Marshall Space Flight Center

Women in the Propulsion and Energetics Industry

For the first time, two women completed an all-female spacewalk outside the International Space Station last October – NASA astronauts Jessica Meir and Christina Koch. NASA plans to put the first woman on the Moon in 2024 as part of the Artemis program. The accomplishments of women are now being recognized more heavily than in the past.

“In the end, I do think it’s important and I think it’s important because of the historical nature of what we’re doing,” Koch said in an interview posted on NASA’s website. “In the past, women haven’t always been at the table. It’s wonderful to be contributing to the space program at a time when all contributions are being accepted, when everyone has a role. That can lead in turn to increased chance for success. There are a lot of people who derive motivation from inspiring stories of people who look like them, and I think it’s an important story to tell.”

Katherine Johnson, a woman whose mind accurately provided the manual calculations for flight paths that were essential for sending a man into space and subsequently to the Moon, passed away in February. Johnson’s story, along with the stories of other African-American women instrumental in the space race, was largely unknown until recent years when a book, movie, and documentaries shared their stories. John Glenn relied so heavily on Johnson’s calculations to keep him safe during his orbit around the Earth, he would not board the spacecraft until she double-checked the computer’s numbers.

For the Spring issue of JANNAF News, we decided to ask a number of the women of JANNAF to reflect on the recent accomplishments of women in the propulsion and energetics industry, and how things have changed for them in their careers over the years. Below are a few of their stories.

Christine Michienzi, Ph.D.

Director, Industrial Assessments

Office of the Secretary of Defense Industrial Policy

Over the course of my career, many things have changed and many things have not, with respect to women in the workplace. When I first started work-



“Human Computer” Katherine G. Johnson whose 33-year career with NASA included calculating the flight trajectory for John Glenn’s first orbital flight during the Mercury Program in the early 1960s. Johnson passed away in February 2020.

ing in the propulsion and energetics industry, I was fortunate to work for an organization that had a lot of female employees, but I soon realized that this was not the norm everywhere. When I would attend meetings outside of my organization, I was often the only woman in the room, and that has not changed completely.

But not all is bleak. During my career, I have seen women rise to very high levels within the government – I work with some of them every day, and it is inspiring. One of the key things I believe women need to do to keep that momentum going is to mentor young women in the workforce. I have made this a priority of my career – I believe it is one of the most important things I do.

I believe that JANNAF provides a unique opportunity to help with this because the JANNAF meetings are such good networking opportunities. I would like to see that taken to the next step. JANNAF could provide opportunities for us more “experienced” women to provide insight and advice to younger women in this industry. This could be done through lectures and workshops, and also one-on-one discussions/



NASA astronauts Jessica Meir (left) and Christina Koch (right) on the International Space Station preparing spacesuits for their historic spacewalk in 2019. Photo courtesy NASA.

mentoring sessions that could be scheduled during regular JANNAF meetings. These types of opportunities would provide young women with the skills and confidence they need to succeed in this industry. Often it just takes encouragement and advice to provide the spark these women need.

Rose Pesce-Rodriguez, Ph.D.

**Army CCDC Army Research Laboratory
Aberdeen Proving Ground, MD**

I honestly don't think much about the scarcity of women in the propulsion field. It's not that I don't realize that there are relatively few women at JANNAF meetings. To tell the truth, I often find myself silently counting the women in the audience and then estimating the fraction of women in attendance. But at the same time, I look around me and see such strong, capable women working in the field that I never feel that it's a problem. At the JANNAF meetings I attend, I see folks from the Navy and Air Force, including Chris Michienzi, Heather Hayden, Lori Nock, Kerry Clark, Sara Pliskin, Su Peiris, and industry colleagues like Sarah Headrick and Kelly

Moran. At JANNAF and back home at ARL, I see senior and mid-career women like Betsy Rice, Jennifer Gottfried, Chi-Chin Wu, Chiung-Chu Chen, and the early career women like Sarah Isert, and I know that while women may be in the minority in the propulsion field, we can certainly hold our own and contribute as well as any male. The thing that I find really wonderful is that (at least over my career) women in propulsion have not had to fight for recognition or respect. This says a lot about not only the women in the field, but also the great men with whom we work.

Despite this, I think that it is critical that women make a conscious effort to mentor young folks and to present themselves as role models. Girls may aspire to be like us, and boys will grow up knowing that it is normal that women are scientists and engineers. In setting ourselves as role models, we all (men and women alike) have a responsibility to conduct ourselves professionally and ethically. This is even more important considering that we in the propulsion community are not just working to make the next "widget," but in support of our national defense.

SPIRITS Software Upgrade Available Through JANNAF

Dear JANNAF Colleagues,

The last official release of SPIRITS-AC (Spectral and In-Band Radiometric Imaging of Targets and Scenes-Aircraft) was c.2010 as SPIRITS-AC2r2. SPIRITS-AC3D (“D” for Developmental) has been in the works since c.1998 and has steadily accumulated capabilities, including handling 3D non-axisymmetric plumes especially pertinent for rotorcraft. Aerodyne, as SPIRITS Industry Coordinator for JANNAF, has long hesitated to “release” AC3 for various reasons, but that landscape has changed. Thanks to Naval Air Warfare Center Aircraft Division, Patuxent River, Small Business Innovation Research funding of our SPIRITS-PLUS project, we now have the magnitude of resources required to issue a release of SPIRITS-AC3(Dr6) that maintains its high quality and provenance, and modernizes its software configuration control and delivery.

Although SPIRITS-PLUS, which builds upon SPIRITS-AC3D, is a work in progress, plenty of rotorcraft modeling capability is presently “bottled up” in AC3D that the community could use today. SPIRITS-AC3D also carries forward all of SPIRITS-AC2r2, which has offered proven utility for modeling fixed-wing turbine engine and turbo-prop aircraft. Users having current JANNAF registration (as recorded by JHU/ERG) will soon be able to download the code, data, and documentation from a secure unclassified website. ERG will continue issuing DVD media for classified targets, and for those users without website access. Further upgrades by the SPIRITS-PLUS project will accrue to SPIRITS-AC3 at no additional cost, and via rolling deliveries from the website. In the July-August timeframe, ERG expects to notify current users with website login and self-service instructions.

Frank J. Iannarilli, Jr.
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45 Manning RD
Billerica, MA 01821 USA

New Signature Modeling Features

- *Ready Now in AC3D*
 - o SPURC3 interface (3D plume radiation)
 - o Artificial Light Sources (Urban Illumination)
 - o Polarization (Atmosphere still unpolarized)
 - o Non-Lambertian Earth emittance/reflectance
 - o Option to invoke external MODTRAN4
 - o “Empirical Plumes” (3D plume spectral radiances extrapolated from measured in band images)
 - o Output convenience options
- *In-development under SPIRITS-PLUS Project*
 - o Workflows supporting multiple CFD vendor 3D flowfields
 - o Unclassified generic rotorcraft sample-cases
 - o Classified CH53E sample-cases
 - o 3D plume secondary reflections off body
 - o LIDAR scattering off body

Other New Features

- *Upon Initial Release*
 - o MSWindows-native or Linux executable codes
 - SPIRITS-AC3 will continue to compile from the same code on all platforms
 - o Identical Python run scripts under MSWindows and Linux
 - o No more need for computer Administrator permissions
 - o Automatic version control of JANNAF and user-contributed fixes and upgrades (Git/CMake)
- *Rolling Releases*
 - o Automated regression testing (“transfer validation”)
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The Call For Papers is Ongoing

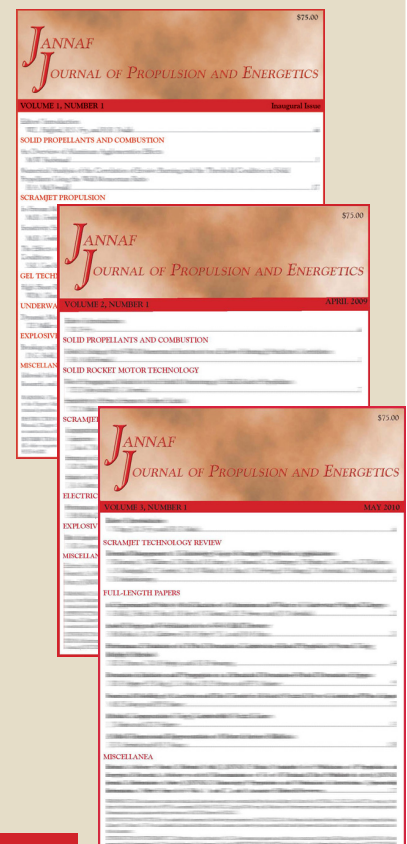
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