FALL 2021

JANNAF NEWS

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

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JANNAF Will Meet Virtually in December 2021

Due to the ongoing global Covid-19 pandemic, the December 2021 JANNAF Meeting will take place in a virtual format from 6-16 December 2021. The featured keynote speaker at the meeting is Lt. Col. Justin L. Beltz, Material Leader and Chief of the U.S. Space Force Launch Enterprise Directorate Small Launch and Targets Division at Kirtland AFB, N.M. A DoD-approved online platform will host all sessions of the meeting, which will feature a joint gathering of the 47th Structures and Mechanical Behavior (SMBS), 43rd Propellant and Explosives Development and Characterization (PEDCS), 34th Rocket Nozzle Technology (RNTS), and 32nd Safety and Environmental Protection (SEPS) joint subcommittee meeting, as well as a meeting of the Programmatic and Industrial Base (PIB). David R. Mattie, Ph.D., with the Air Force Research Laboratory (AFRL) / 711 Human Performance Wing at Wright-Patterson AFB, Ohio, will chair the meeting.

Lt. Col. Beltz's keynote speech, entitled "Expanding Opportunities in Small and Responsive Launch," will focus on the role that the U.S. Space Force Launch Enterprise plays in providing a spectrum of launch solutions to meet the full range of National Security Space needs. The small and responsive launch

David R. Mattie, Ph.D., of the Air Force Research Laboratory/711 Human Performance Wing at Wright-Patterson AFB, Ohio, will chair the JANNAF Meeting.

(See December 2021 Virtual Meeting on page 3)

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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

- Abstract Number: 2021-0001
  Meeting Proceedings of the 68th JANNAF Propulsion Meeting (JPM) / Programmatic and Industrial Base (PIB) / 15th Modeling and Simulation, 12th Liquid Propulsion, and 11th Spacecraft Propulsion Joint Subcommittee Meeting
  Jun 2021

- Abstract Number: 2021-0018
  United States Rocket Research and Development During World War II
  Jun 2021

- Report Number: JANNAF-PIB-2021-0015
  JANNAF PIB Integrated Program Plan and Key Decision Point Report
  Jul 2021

- 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 Linda McLean at lmclean@erg.jhu.edu.

December 2021 Virtual Meeting... *continued from page 1*

segment is an exciting part of this spectrum, leveraging a burgeoning industrial base to bring unprecedented flexibility, increased competition, and rapid growth in capability. In partnership with industry, the Launch Enterprise has achieved groundbreaking successes, with even greater opportunities on the horizon.

Lt. Col. Justin L. Beltz entered the Air Force in 2007 as a graduate of the Reserve Officer Training Corps at California State University – Fresno. He has served in a variety of acquisition and contracting positions. He transferred to the Space Force in 2021. Prior to his current position, Lt. Col. Beltz served as Chief, Congressional and Media Affairs, Directorate of Space Programs, Assistant Secretary of the Air Force (Acquisition, Technology & Logistics), Washington, D.C. He also served as Chief, Rocket Acquisition Branch, Office of Space Launch, National Reconnaissance Office, Los Angeles AFB; Aide-de-Camp, Space & Missile Systems Center, Los Angeles AFB; Lead, EELV Competitive Acquisitions, Launch Enterprise Systems Directorate, Los Angeles AFB; and Contracts Manager, 9th Contracting Squadron, Beale AFB, California. In 2012, he deployed to Southwest Asia to support OPERATION ENDURING FREEDOM as Operations Officer, CENTCOM Joint Theater Support Contracting Command. In his current role as the Materiel Leader and Chief, Small Launch and Targets Division, Launch Enterprise Directorate, Space and Missile Systems Center, Kirtland AFB, N.M., Lt. Col. Beltz leads the Rocket Systems Launch Program in providing mission planning, payload integration, vehicle acquisition, processing, launch operations, booster storage and disposition, aging surveillance, maintenance, and logistics support for selected Department of Defense responsive small and RDT&E launches.

Lt. Col. Justin L. Beltz, Materiel Leader and Chief of the U.S. Space Force Launch Enterprise Directorate Small Launch and Targets Division at Kirtland AFB, N.M., will be the keynote speaker at the virtual JANNAF Meeting.

For complete details on all the papers and topics at the December 2021 JANNAF Meeting, please see the meeting program, which is available through the JANNAF Portal at https://www.jannaf.org/mtgs/2021Dec/pages/index.html.

The December 2021 JANNAF Meeting will be conducted via a DoD-approved virtual platform that meets DoD security requirements for presentation and discussion of ITAR-restricted material, and has DoD-wide approvals and authorizations for configuration and use. Detailed information, including technical specifications and participation guidelines, will be provided soon.

December 2021 Meeting Subcommittee Highlights

SMBS

The 47th Structures and Mechanical Behavior Subcommittee (SMBS) will host three sessions at the December 2021 JANNAF Meeting. SMBS will also host a joint specialist session with the Propellant and Explosives Development and Characterization Subcommittee and a joint session with the Rocket Nozzle Technology Subcommittee. SMBS will convene five panel meetings covering a wide spectrum of topics within the SMBS areas of interest. Each panel meeting will allow dialog among attendees to discuss upcoming technical issues and future areas of possible focus for the subcommittee.

PEDCS

The 43rd Propellant and Explosives Development and Characterization Subcommittee (PEDCS) will convene 14 technical sessions, one two-part workshop, and two specialist sessions to provide a forum for sharing advances in emerging research required to develop, manufacture, and characterize propellants and ingredients. Technical sessions will address modeling, synthesis, processing, optimization, and characterization of liquid and solid propellants.

A joint PEDCS/Structures and Mechanical Behavior Subcommittee specialist session is intended to provide the JANNAF community an overview of recent advances in energetics manufacturing that promise to reduce the time and cost of production, remove barriers limiting system performance, and inspire more uses of these technologies than previously envisioned.

The Cylinder Expansion (CylEx) Test workshop will provide an opportunity to discuss the creation of a standard and determine minimum requirements for the cylinder expansion test, with a goal of greater ease of sharing of test data. The Polyglycidyl Nitrate (PGN) specialist session will provide a forum for collaborative discussions of synthesis techniques, programs to support raw material demand, and evaluate alternative enabling chemistries. Additionally, PEDCS will team with the Safety and Environmental Subcommittee to convene the Green Energetics Materials (GEM) technical session and panel meeting to address developments in energetic ingredients, formulations, and processing technologies that permit enhanced recycling, recovery, reuse, and waste reduction during manufacture, testing, operations, and demilitarization.

RNTS

The 34th Rocket Nozzle Technology Subcommittee (RNTS) will have four sessions, one joint session with the Structures and Mechanical Behavior Subcommittee, and three panel meetings to discuss and exchange information on recent technical developments in nozzle thermal, structural, and fluids analysis and modeling; nozzle design, test, and evaluation; and thrust control technology. Discussions during the panel meetings will explore new directions of interest and shape future emphasis areas or cross service efforts in the nozzle technology community.

SEPS

The 32nd Safety and Environmental Protection Subcommittee (SEPS) sessions will include presentations that address the toxicity of Insensitive High Explosives (IHE), the potential use of bioderived thermoplastics for additively manufactured (AM) rocket fuel, and a summary of pending changes to the regulatory status for emerging contaminants tracked by the Office of the Secretary of Defense Emerging Chemicals Program. SEPS will convene a specialist session that features a speaker from the U.S. Environmental Protection Agency to discuss policies related to open burn/open detonation (OB/OD) as well as alternative technologies to OB/OD. In addition, the SEPS Blast Injury specialist session aims to enhance the JANNAF community's understanding of the impacts of blast pressure exposure from weapon systems to brain health, increase awareness of blast exposure resources and requirements, and better inform decisions for blast risk mitigation.

2021 JANNAF-PIB Integrated Program Plan and Key Decision Points Report Published

The JANNAF Programmatic and Industrial Base Committee (PIB) serves as a forum that identifies risks and opportunities for interagency program collaboration in the propulsion industrial base. It supports the synchronization of rocket propulsion industrial base related activities across National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD) via a senior leader forum and working-level processes that:

- Leverage existing forums and processes to the maximum extent possible
- Minimize additional costs and resource burdens
- Identify key products and processes required to support senior leaders' discussion and decision-making
- Align with current interagency and Department-level forums.

The seven JANNAF PIB Working Groups span the complete rocket propulsion industrial base and work diligently to collect program information within their respective sectors: large solid propulsion, small solid propulsion, large liquid propulsion, small liquid propulsion, electric propulsion, propulsion-related efforts in science and technology (S&T), and propulsion test and evaluation (T&E).

The PIB satisfies the critical need for formalized regular programmatic and industrial base communication and strategic planning across DoD and NASA systems. Data are gathered and analyzed to help identify, predict, and preempt potentially serious industrial base risks, and provide opportunities for programmatic integration and collaboration. From deliberations at the working-group level, special technical interchange meetings have been held in areas such as: green propellants, understanding interagency RL-10 production expectations, solid rocket motor formulation strategies, and reuse of first-stage rocket propulsion systems.

The PIB released the 2021 Integrated Program Plan and Key Decision Points (IPP & KDP) Report in July 2021. The report and its key findings, which include technology and supply chain issues and recommendations for important actions, have been presented to DoD and NASA senior leadership for their situational awareness and for opportunities to take action on key recommendations.

The more-than-130-page presentation details current collaboration efforts between programs, identifies technical and programmatic risks, and explores areas for further dialogue. Included are topics related to the industrial base, along with indicators that give insight into the health of the domestic supply chain necessary for meeting civil and military rocket system requirements.

The IPP & KDP Report is CUI and releasable to U.S. Government personnel only because it contains company-sensitive information. To access the report, please email info@erg.jhu.edu.

The JANNAF PIB is co-chaired by Christine Michienzi, Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, the Department of Defense (DoD), Alexandria, Va., and Tom Brown, Ph.D., NASA Marshall Space Flight Center, Huntsville, Ala. The PIB's ERG representative is Kirk Sharp. They may be contacted to request additional information about the PIB and/or the 2021 IPP & KDP report. Kirk Sharp (ksharp@erg.jhu.edu)

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JANNAF Meets Virtually for June 2021 Meeting

The JANNAF community met in June for its first virtual meeting of 2021. Due to the Covid-19 pandemic, participants in the 68th JANNAF Propulsion Meeting (JPM), Programmatic and Industrial Base (PIB) Meeting, and the 15th Modeling and Simulation (MSS), 12th Liquid Propulsion (LPS), and 11th Spacecraft Propulsion (SPS) joint subcommittee meeting gathered online using the Defense Information Systems Agency's Defense Collaboration Services (DCS) online platform for all sessions and panel meetings. James L. Cannon of the NASA Marshall Space Flight Center (MSFC) in Huntsville, Ala., chaired the two-week meeting. Lakiesha Hawkins, the Deputy Manager for NASA's Human Landing System (HLS) Program Office at MSFC gave a keynote speech discussing the current status of NASA's Artemis lunar exploration program with a specific emphasis on the HLS component.

Hawkins began her presentation by discussing the key phases of NASA's Artemis Program, which aims to return humans to the South Pole of the Moon in the decade of the 2020s. The midterm goal of the program is a sustained human presence on and around the Moon by 2028, and the long-term goal of Artemis is to use the lessons learned from the program to structure a future mission to Mars. Hawkins discussed the necessary components for the Artemis Program, including the Space Launch System heavy-launch booster, the Orion spacecraft, the Lunar Gateway in near-rectilinear halo orbit around the Moon, and the HLS vehicle to transfer astronauts between the Lunar Gateway and the surface of the Moon. Each of these elements is in development by NASA and its contractors. Artemis I and II, respectively, will offer unmanned and manned lunar flight demonstrations of the Orion spacecraft and lay the groundwork for the Artemis III mission, which will involve a rendezvous with the Lunar Gateway and HLS in lunar orbit and a

Keynote speaker Lakiesha Hawkins, the Deputy Manager for NASA's Human Landing System Program Office at Marshall Space Flight Center, Huntsville, Ala.

descent to the lunar surface. Two astronauts will land on the Moon and conduct scientific research activities before returning to the Gateway and the Orion spacecraft.

Hawkins explained that the HLS Program Office is currently issuing bids for the development of the HLS hardware in an expedited manner. NASA will purchase use of the vehicle from commercial partners, rather than take ownership of it, much like the agency currently does with its Commercial Resupply Services and Commercial Crew Programs for the International Space Station. Like these programs, NASA will apply its spaceflight experience and expertise to ensure mission safety and success. A number of contractors, including Space X, Blue Origin, and Dynetics, have proposed landers that meet the NASA HLS requirements, but due to a formal protest over the selection process, Hawkins was unable to discuss specifics regarding the various firm's lander proposals. Hawkins highlighted key challenges in the development of HLS hardware, including vehicle mass concerns, the ability to operate in both microgravity and lunar gravity, the use of cryogenics in the pro-

pulsion system rather than hypergolics, a potential refueling capability, and the potential ability to make use of in-situ propulsion resources on the Moon.

Looking forward, NASA plans to issue bids for a recurring services support contract for lunar transportation in support of long-term lunar habitation. The agency also expects to use the lessons learned from the lunar exploration and habitation program to develop future Mars missions. As Hawkins noted, the Moon is only a few days away from Earth, so NASA could use the Artemis Program to test hardware and mission procedures with far less risk than that incurred on a years-long mission to Mars and back. She expressed hope that the Artemis Program would continue to advance rapidly and meet its objectives by the end of the 2020s, and she encouraged JANNAF Meeting participants to follow along with the program's development through NASA social media outreach.

Following Hawkins' keynote address, James Cannon introduced JANNAF Technical Executive Committee (TEC) Chair Drew DeGeorge of the Air Force Research Laboratory (AFRL), Edwards Air Force Base, Calif., who thanked JANNAF Meeting authors, coauthors, and other participants on behalf of the TEC for their willingness to participate in the online meeting. He hoped that all meeting participants would enjoy the sessions and receive information that would be of value to them in their current roles. DeGeorge also announced that the December 2021 JANNAF Meeting would be held virtually due to ongoing uncertainty regarding the evolving Covid-19 situation. He concluded by expressing hope that the Spring 2022 JANNAF Meeting would be held in person if circumstances permitted.

After DeGeorge's remarks, PIB Co-Chair Christine Michienzi, Ph.D., Office of the Secretary of Defense for Acquisition, Technology, and Logistics, Manufacturing and Industrial Base Policy, the Department of Defense (DoD), Alexandria, Va., addressed participants on behalf of the PIB. Michienzi highlighted PIB activities within JANNAF, including a JANNAF Meeting session on launch vehicle reusability and the pending release of the 2021 Integrated Program Plan and Key Decision Points (IPP & KDP) Report on 1 July. The biannual report examines program activities within NASA and the DoD and how they may impact the U.S. industrial base. More information about the IPP & KDP Report may be found on page 5 of this issue. Michienzi concluded her remarks by echoing DeGeorge's appreciation of JANNAF Meeting participants' willingness to join the sessions remotely and her hope that in-person meetings would resume as soon as possible.

JANNAF is pleased to announce the following awards

JANNAF Propulsion Meeting
Lifetime Achievement Award

Frank Tse
Naval Surface Warfare Center,
Indian Head, Md.

For his outstanding, selfless dedication to the field of energetics, endless commitment to enabling, training, and mentoring future scientists and engineers, vast knowledge of rocket propulsion systems, and long-standing leadership within the national and international propulsion communities that has resulted in, among other things, the development of the standard for mechanical properties testing of solid propellants and other seminal references within the community.

Technical Executive Committee
Sustained Contribution Award

Steven F. Son, Ph.D.
Purdue University, West Lafayette, Ind.

In recognition of outstanding dedication, service, and leadership to the entire JANNAF community as Editor-in-Chief of the JANNAF Journal of Propulsion and Energetics from 2013–present.

SPS Best Paper Award
2019 JANNAF Meeting, Tampa, Fla.

Hani Kamhawi, Ph.D.
Jason D. Frieman, Ph.D.
NASA Glenn Research Center,
Cleveland, Ohio

Congratulations to all award recipients!

June 2021 Virtual Meeting Subcommittee Review

MSS

The 15th Modeling and Simulation Subcommittee (MSS) met virtually in June 2021 in conjunction with the Liquid Propulsion and Spacecraft Propulsion Subcommittees and the JANNAF Propulsion Meeting. Session topics included uncertainty quantification using the probability box approach, a technique popularized by Northrop Grumman. A guide on how to use the approach was completed and will soon be made available to the JANNAF community on JDOC (the JANNAF Digital Online Collection) on the JANNAF website. As it has done in previous meetings, MSS held a tool demonstration session. For this meeting, the session focused on the Generalized Fluid System Simulation Program (GFSSP) and the Rocket Engine Transient Simulation (ROCETS) software. MSS also held a session on fluid analysis of supersonic and space system components.

In addition to its regular sessions, MSS hosted a plenary talk by Venke Sankaran, Ph.D., Senior Scientist for Rocket Propulsion for the Aerospace Systems Directorate at the Air Force Research Laboratory, Edwards AFB, Calif., on the future of modeling and simulation and how the topic intersects with developments in digital engineering and digital twins. He focused on research and development needs with respect to liquid rocket and in-space electric propulsion systems.

LPS

The 12th Liquid Propulsion Subcommittee (LPS) met virtually from 7-17 June 2021 on the Defense Collaboration Services online platform as part of the JANNAF Propulsion Meeting. Forty-nine presentations were spread across nine technical sessions covering liquid engine systems analysis, combustion subsystems and components, propellant feed and pressurization systems, as well as advanced materials research and development within these applications. Specific topics of interest covered in the LPS sessions included propellant characterization and performance, the use of additive manufacturing in rocket engine systems, and research into rotating detonation rocket engines.

Additionally, a brand new LPS panel, the Rotating Detonation Rocket Engine (RDRE) Panel, met for the first time after a full and engaging session of RDRE papers. Co-chairs Eric Paulson, Ph.D., Air Force Research Laboratory (AFRL), Edwards AFB, Calif., and Doug Perkins, Ph.D., NASA Glenn Research Center, Cleveland, Ohio, gave a brief overview of the panel's mission and focus, primarily the technology development requirements for RDRE design, manufacturing, modeling, and experimental testing. Other topics of interest to the RDRE community included potential NASA/AFRL collaborations, thermodynamic models of liquid and gas propellants in RDREs, and performance standards for RDREs. The decision was made to establish the panel at the December 2019 LPS Meeting in Tampa, Fla., following several years' worth of interest and research into the fundamentals of RDREs from across the JANNAF community.

SPS

The 11th Spacecraft Propulsion Subcommittee (SPS) met virtually in June 2021 for two weeks of sessions spanning its four mission areas: advanced propulsion, electric propulsion, chemical propulsion, and micropropulsion. Additionally, the subcommittee hosted four workshops as part of the SPS meeting.

The first SPS workshop focused on the status of hydrazine and monomethyl hydrazine (MMH), as producers of these hypergolic propellants are switching over from the traditional Raschig manufacturing technique to the newer ketazine production process.

The second workshop proposed a joint approach for identifying and selecting advanced spacecraft propulsion concepts that may have a transformative impact on the field of spacecraft propulsion. Speakers focused on current strategies and challenges for conducting transformative research, as well as methods for selecting which projects to fund from a program management standpoint.

The third SPS workshop, addressed the topic of electric propulsion operation in the space environment (EPOSE) and test facility interactions. This is the fifth workshop thus far on the topic, and it furthered the community's ongoing discussion regarding the current status of electric propulsion projects and data analysis techniques.

The last workshop focused on flight qualification requirements for nuclear thermal and nuclear electric propulsion systems for use on human Mars missions. The introductory workshop reviewed current flight qualification requirements, determined how they may be applied to nuclear propulsion missions, and evaluated forthcoming challenges and potential changes to requirements as research and development on these systems moves forward.

JANNAF is pleased to announce the Best Student Paper from the June 2021 JANNAF Meeting

Student/Primary Author:

Louis Villa

Authors:

Louis Villa

Alicia Benhidjeb-Carayon, Ph.D.

Amy Marconnet, Ph.D.

Timothée Pourpoint, Ph.D.

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JANNAF Journal Volume 12

The *JANNAF Journal of Propulsion and Energetics* Volume 12 will be available shortly online in JDOC, and hard copies of the last few volumes will be available at the next in-person conference.

In Memoriam

Benjamin Hill-Lam, a research engineer with the Johns Hopkins University's Energetics Research Group (ERG), died suddenly on Sunday, August 15.

Ben was born at the Sibley Hospital in Washington, D.C., on May 13, 1991. He grew up in Olney, Md., and graduated from Sherwood High School in Sandy Spring, Md.

Ben joined ERG in 2014 and worked in its AERoFuels Laboratory, where he played a key role in the development of experimental apparatus used for precisely producing and testing mixtures of cryogenic methane-based fuels. He also led testing and analysis for the evaluation of cooling channels for heavy hydrocarbon-fueled rocket engines, and supported JANNAF, working closely with the Liquid Propulsion and the Combustion Subcommittees.

During his seven years with Johns Hopkins, Ben authored or co-authored 29 papers, including 18 for JANNAF, as well as other papers, presentations, and posters at professional organizations ranging from the Intersocietal Accreditation Commission and the Institute for Advanced Studies in the Humanities, to the American Institute of Aeronautics and Astronautics, the Institute of Electrical and Electronics Engineers PSWT, the Defense Systems Information Analysis Center, the Commercial and Government Responsive Access to Space Technology Exchange, and the DoE National Energy Technology Laboratory Crosscutting Technology Review.

He earned a bachelor's degree in physics and astronomy at Bowdoin College in 2013, and his master's degree in materials science and engineering in 2020 through the Johns Hopkins University Whiting School of Engineering's Engineering for Professionals program.

Ben used his expertise and knowledge during the pandemic as part of the team that developed a prototype for a pumpless ventilator that could run 24 hours on a single 12-volt battery—work that resulted in a letter of commendation from the Johns Hopkins University's Board of Trustees.

At the time of his death, he was working on a new synthetic fuel that could revolutionize hypersonic propulsion systems and make operational hypersonic vehicles a reality.

Benjamin Hill-Lam (1991-2021)

Ben loved to read and play video games. He also loved animals and enjoyed the great outdoors. In the past few years, he had hiked and camped on different small sections of the Appalachian Trail in Virginia and West Virginia. Rock climbing became a passion in recent years. Ben was a gourmand and developed a talent for cooking and baking. He was a Black Belt holder and a Junior Instructor of Karate while in high school.

He is survived by his father, See-Yan Lam. His mother, D. Robin Hill, passed away in 2000 from breast cancer. Ben had a wide circle of friends from high school and college, and from his jobs and many hobbies. He will be remembered by colleagues not only as an excellent engineer and researcher, but also as a role model who exemplified kindness, empathy, and respect for all.

In Memoriam

George C. Harting, Ph.D., a long-time member of the JANNAF community, passed away on May 26, 2021, at the age of 51. For more than 20 years, Harting contributed papers and research to JANNAF in his area of expertise, solid rocket motor propellants and performance. Harting was born to Arnulfo and Leonila Harting (née Carrillo) in Chicago, Ill., on February 12, 1970. He received a B.S. in mechanical and aerospace engineering from the University of Illinois at Urbana-Champaign and later an M.S. and a Ph.D. from the Pennsylvania State University. His 2000 dissertation focused on pyrolysis and combustion in hybrid-rocket propellant materials.

In the mid-1990s, Harting went to work as a civilian Department of Defense employee at the Air Force Research Laboratory (AFRL), Edwards AFB, Calif. He remained at AFRL for more than 27 years, advancing from an engineer and project manager to a Senior Technical Advisor for the Solid Rocket Motors Branch. He received the Civilian Achievement Award Medal in 2011 for his service and accomplishments on behalf of the United States Air Force and the Department of Defense and the Don Ross Distinguished Performance Award in 2019 for multiyear research and engineering work in solid rocket motor technologies in support of Air Force space, science, and technology objectives.

George C. Harting (1970-2021)

In his free time, Harting enjoyed being in the outdoors, playing guitar, and spending time with family. He is preceded in death by his parents and survived by his siblings, Arnel, Milrose, Arnold, and Arlene; nephew, Kela; nieces, Leilani and Ines; and aunts, uncles, and cousins.

In Memoriam

The JANNAF community is saddened to learn of the passing of John P. Consaga on August 20, 2021 at the age of 81. Consaga was active in JANNAF from 1971 through 2011 and authored numerous papers on solid propellant formulations and properties, his particular areas of expertise. Consaga was born on July 9, 1940, in the village of Ossining, N.Y. After graduating from high school in 1958, Consaga attended Washington College in Chestertown, Md., where he majored in chemistry, graduating with a B.S. in 1962. He later pursued graduate education at the University of Maryland and received an M.S. in chemistry in 1969.

Consaga began his career as a solid propellants technologist at the U.S. Naval Surface Warfare Center's (NSWC) White Oak Laboratory Research Department in Silver Spring, Md., in

John P. Consaga (1940-2021)

(See Consaga on page 12)

In Memoriam

Douglas Ernest Coats, Founder and Chairman of the Board of Software and Engineering Associates (SEA), Inc., died peacefully at his home in Carson City, Nev., on August 7, 2021, after a long battle with cancer. An aerospace engineer, he, with others, did groundbreaking work in rocket propulsion and rocket propulsion modeling. Coats was one of the principal architects of a series of rocket propulsion software tools (SPP, TDK, and VIPER) that have become the gold standard in the aerospace industry. Today, these codes are still widely used and still very much in demand.

Douglas E. Coats was born on November 2, 1941, in St. Paul, Minn., to Louis David "Bill" Coats Sr., and Ouida Coats (née Moulton). Coats' family lived in the Midwest, mostly in Perry, Iowa, until 1951, when they moved to North Carolina. He received a B.S. in mechanical engineering from the North Carolina State College in 1960. After receiving encouragement to pursue a career in rocket propulsion, Coats relocated to California and earned an M.S. in aerospace engineering from the University of Southern California in 1967. He founded SEA, Inc., in 1975 in Santa Ana, Calif., and later relocated the company to Carson City, Nev., in 1985.

Douglas E. Coats (1941-2021)

Coats' publications include over 100 technical reports, meeting papers, and journal articles. In 2019, JANNAF presented Coats and his team at SEA, Inc., with a Lifetime Achievement Award "in recognition of over 30 years of outstanding leadership and technical contributions. . . ." Their codes and "contributions to the industry and state of the art have stood the test of time. . . ."

Coats is survived by his wife, Judith Epstein, and daughters, Alexandra Coats and Victoria Coats. He is also survived by a brother, Louis David Coats Jr., and two sisters, Deane Dierksen and Donna Sevilla. He was a man who lived a full life and will be missed by family, friends, and all of his colleagues at SEA, Inc.

Courtesy of Dr. Homayun Navaz

Consaga... *continued from page 11*

1968 and later worked at the NSWC's Indian Head Division in Indian Head, Md. He received patents for innovations in propellant bonding agents, insensitive propellants, liquid fuels, and other topics, and presented his research at domestic and international conferences. Consaga also received numerous performance awards during his civil service career with the Navy, including the Admiral Wayne E. Meyer Award for acquisitions excellence. In addition to his research, Consaga taught college-level courses related to his subject matter expertise. He retired from the NSWC in 1998 but continued consulting on solid propellants until his death.

Upon retirement, Consaga relocated with his family to Bolton Landing, N.Y., where he became deeply involved with the local Catholic Church community and volunteered his time as a Meals on Wheels driver and a board member of a nonprofit focused on alcohol and drug rehabilitation. He also served as the president of the Bolton Landing Senior Citizens Association. In his free time, he enjoyed cooking and entertaining guests.

Consaga is predeceased by his parents and older brother, Joseph, and survived by his twin brothers, Robert and Thomas, and wife, Patricia, as well as numerous nieces and nephews.

Validation of Navier-Stokes Codes for Scramjet Combustors

In 1989, at the Airbreathing Propulsion Town Hall Meeting, part of the 26th JANNAF Combustion Subcommittee Meeting, attendees discussed advances in computational fluid dynamics (CFD). Refinements in numerical algorithms, physical models, grid generation, and the expansion of computational resources had elevated the three-dimensional Navier-Stokes computer codes into a conceivable engineering design and analysis tool for modeling scramjet combustors. To gauge the accuracy and efficiency of the codes, attendees decided to schedule the first of three workshops for July of the following year in Orlando, Fla., following the 26th AIAA/SAE/ASME/ASEE Joint Propulsion Conference.

Clifford Smith of the CFD Research Corporation organized each of the workshops and presided over the initial one. The workshop, entitled "Scramjet Combustor Modeling," included 22 participants. Fourteen validation or test cases/experiments were reviewed and narrowed these cases to three for further consideration and CFD competition. Michael S. Holden, Ph.D., of CUBRC performed a two-dimensional, nonreacting flow experiment in which a Mach 3 planar wall jet discharged into a Mach 6 freestream. William Peschke of United Technologies Research Center performed a two-dimensional, reacting flow experiment in which a sonic hydrogen wall discharged into a Mach 2.77 freestream. Finally, Doug Fletcher, Roy Hartfield, and Jim McDaniel of the University of Virginia (UVA) performed a three-dimensional, nonreacting flow experiment in which two jets of air discharged behind a step into a Mach 2 freestream crossflow.

A computationalist was appointed for each of the three cases, providing turbulence models based on CFD codes for comparison with the empirical data collected from the experiments. These calculations and the experimental results were presented at a second workshop held during the 29th Aerospace Sciences Meeting in Reno, Nev., in January 1991. The sources of discrepancy between the computational solutions and the outcomes of each experiment were weighed. The results of the UVA experiment demonstrated the most promise in validating the codes. The experiment displayed sizeable in-stream data, contained a flow of a three-dimensional nature, and possessed well-defined boundary conditions. The specifics of the UVA experiment were later shared with the CFD modeling community.

The following year, a third workshop convened and seven organizations presented solutions from six CFD codes for the UVA experiment at the conclusion of the 30th Aerospace Sciences Meeting in Reno, Nev. The organizations and their respective codes (listed in parentheses) were as follows: Aerosoft, Inc. (GASP), Boeing Defense and Space Group (GIFS), CFD Research Corporation (REFLEQS), NASA Langley Research Center (SPARK), NASA Lewis Research Center (RPLUS), Rockwell International (USA) and Wright-Patterson AFB (GASP). The solution by Wright-Patterson AFB was excluded as it failed to account for the viscous effects in span and the direction of the stream.

The preponderance of experimental measurements was accomplished through laser-induced iodine fluorescence (LIIF) techniques developed at UVA. LIIF techniques are noninvasive optical techniques used to infer flow field properties from signals emitted by the laser-induced fluorescence of iodine molecules seeded into the flow. Likewise, the Navier-Stokes codes employed a finite volume formulation (FV) with the exception of the SPARK code, which used a finite difference formulation (FD). All the codes made use of structural grids and provided choices in both algorithm and turbulence models. Each organization recorded boundary conditions, grid spacing, specific turbulence model, and final computations specific to the code.

The numerical solutions exhibited wider code-to-code variation than expected. The source of deviation was attributed to the contrasting turbulence models of each code as the respective turbulence fields fluctuated appreciably between the calculations and the calculations and the measurements.

Due to the abundance of data, a statistical measure of agreement was accepted to provide a gross measure of agreement. The sources of error in the

(See Scramjet Combustors on page 15)

ERG Welcomes New Staff

The Energetics Research Group (ERG) recently brought on a number of new staff members who will be supporting ERG/JANNAF activities.

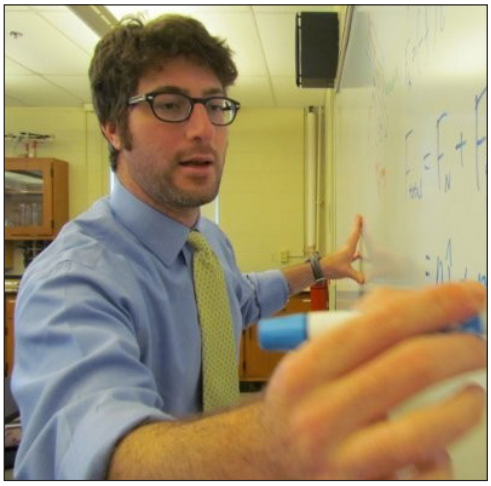
Leslie Thompson

Leslie joined ERG in June of 2021 as the Financial Operations Lead. She previously worked in the Business Office of Johns Hopkins University's (JHU's) Whiting School of Engineering (WSE). Thompson manages ERG's financial team of three and all of its finances, including the budget for the JANNAF contract, as well as budgets for some of WSE's and ERG's other endeavors and mission areas. Originally from Baltimore, Thompson holds a Master of Science in Business Finance from JHU. She brings more than 25 years of finance experience to the team, having worked for three large corporations in the Baltimore area before joining JHU in 2016.

Financial Operations Lead Leslie Thompson

Adam Fuller

Adam Fuller started at ERG in May of 2021 as a software engineer. He previously worked for the JHU Press for eight years as a senior programmer analyst, building and supporting websites for the Press and its academic clients as well as building and supporting the underlying website architecture. Fuller now supports ERG's IT department and JANNAF's IT needs. He is assisting with the upgrade of the JANNAF website from Drupal 7 to Drupal 9 by rewriting major applications such as JDOC (the JANNAF Digital Online Collection), web user account verification tools, and the web meeting management tools. Born in Mississippi, Fuller was raised in North Carolina and lived in New York City before moving to Baltimore 12 years ago for graduate school. He holds bachelor's degrees in journalism and astrophysics from UNC Chapel Hill and Columbia, respectively. He also has two master's degrees from Johns Hopkins University in creative writing and planetary science with a specialization in atmospheres. In his spare time, he enjoys running, writing fiction, and reading. Fuller says he loves talking about books and getting book recommendations.



Software Engineer Adam Fuller

Michael "Miki" Fedun

Michael "Miki" Fedun has been working part-time at ERG for a few years, and has attended a couple of recent JANNAF meetings. He presented work at several JANNAF conferences in 1988 and 1989 while employed at Aerojet. Fedun recently joined ERG as a full-time employee in 2021, and will be supporting the JPM and the Modeling and Simulation Subcommittee (MSS) as ERG's technical liaison. Fedun previously worked for the Defense Threat Reduction Agency (DTRA) for 16 years, acting as the foreign propulsion subject matter expert and contractor support to the Strategic Offensive Arms Elimination (SOAE) program within the Cooperative Threat Reduction directorate in eliminating Cold War Soviet ICBMs in Russia and Ukraine. He became interested in Russian propulsion when he tested a divert thruster from

Technical Representative Michael "Miki" Fedun

the Buran (USSR's version of the Space Shuttle) back in 1994 while working at Aerojet. He went on to serve as the technical liaison between Lockheed Martin and Energomash during the integration of the RD-180 Russian engine into the Atlas III/V launch vehicles. Being able to speak both Ukrainian and technical Russian helped in his roles at Aerojet, Lockheed, and DTRA. He holds bachelor's and master's degrees in mechanical engineering from Rensselaer Polytechnic Institute. Originally from Cleveland, Ohio, and having raised his children in Virginia (via California and Colorado), he now lives in Austin, Texas, where he indulges his passion for live music, good food, and looking for material to write about.

Peyton Nanney

Peyton Nanney began working at ERG in June of 2021 as a lab technician. He is supporting the AERoFuels Laboratory, which primarily tests rocket fuels. He previously studied physics at the University of Tennessee and appreciates the hands-on problem solving required in experimental work. Nanney is originally from Kingsport, Tn. In his spare time, he enjoys stargazing and astrophotography.

AERoFuels Lab Technician Peyton Nanney

Scramjet Combustors...

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numerical solutions in order of importance were turbulence models, grid resolution and the lack of grid adaptation to features of the flow, and, lastly, the fidelity of the circular exit of the jet, the uncertainty in Mach number at the exit of the jet, and the jet model itself. The differences in turbulence models and computational grids were suspected to have a greater impact upon the numerical solution than the algorithm. Nonetheless, the complications resulting from the differences in the algorithm, the computational grid, and the turbulence model together made the prevailing source of discrepancy in numerical solutions indiscernible.

The third workshop deepened the understanding of the process by which code validation might be achieved. Future efforts would necessitate the performance of two calculations on a selected baseline grid. The first calculation would be realized without a turbulence model or, alternatively, an agreed-upon model. The comparisons of resulting solutions would isolate the effect on the numerics of each code and define their respective efficiency. The second computation would be executed with a turbulence model of choice, again supporting the effort to separate the effect of turbulence models from the solution. Lastly, with the expectation of turbulence field modeling and its relationship to shock waves and shear layers within the three-dimensional flow field continuing to advance, the participants and organizers anticipated future collaborations/competitions. Indeed, three more JANNAF-sponsored computational fluid dynamics workshops would follow in the 1990s, enhancing CFD code validation and calibration.

From Eklund, D.R., Burton, G.B., McDaniel, J.C., Smith, C., *Workshop Report: A Validation Study of Navier-Stokes Codes for Transverse Injection Into A Mach 2 Flow,* CPIA-PUB-593-VOL-II (1994). Available on JDOC (the JANNAF Digital Online Collection) via the JANNAF website at www.jannaf.org.

EPSS Leadership Change

Kevin D. Kennedy, Ph.D., DEVCOM Aviation & Missile Center, Redstone Arsenal, Ala., is stepping down from his role as Deputy Chair of the Exhaust Plume and Signatures (EPSS) Subcommittee in conjunction with his retirement from government service. Dr. Kennedy chaired EPSS from 2007 to 2010 and has served as Deputy Chair of EPSS since 2019. He is a long-time member of JANNAF and has presented papers at numerous meetings over the past three decades. Most recently, Dr. Kennedy served as the Meeting Chair in December 2020.

Commercial "New Space" 2021 Roundup

Young commercial space launch companies in the United States have had a busy and impactful year thus far. Below is a roundup of major 2021 accomplishments by seven that have participated in JANNAF over the past decade.

Blue Origin

On July 20, Amazon and Blue Origin founder Jeff Bezos completed a suborbital spaceflight accompa-nied by his brother, Mark Bezos; Wally Funk, the 82-year-old aviation pioneer (and one of the original Mercury 13 female trained astronauts); and Oliver Daemen, an 18-year-old, on Bezos's New Shepard rocket. In doing so, Funk and Daemen became the oldest and youngest persons, respectively, to fly to space. Billionaire Bezos and his guests launched on New Shepard S/N 4 (NS4) from a facility in Texas, ascended to approximately 107 kilometers in altitude, experienced four minutes of microgravity at the peak of the parabolic flight, reentered the atmosphere, and then completed their descent and landing by parachute, touching down 10 minutes and 10 seconds after the launch. The New Shepard booster NS4 (previously flown twice before), which is powered by liquid hydrogen and liquid oxygen, also descended under its own control and landed propulsively back at the launch site. The flight marks the first manned test of the New Shepard rocket, which will be used to launch space tourists as part of Blue Origin's business model.

Blue Origin continues to develop its BE-4 methane-and oxygen-fueled rocket engine for use by United Launch Alliance (ULA) on its new Vulcan rocket. The Vulcan will employ two of the BE-4s, which generate approximately 550,000 pounds of thrust, on its first stage. The rocket engine has experienced development difficulties and is behind schedule, likely delaying the first launch of the Vulcan into 2022. While the rocket engine has been tested by itself, it will need to be integrated with the Vulcan launch vehicle and then hot fired prior to any launch attempts by ULA. Blue Origin also intends to use the BE-4 on its own launch vehicle, New Glenn, which may compete for some of the same launch customers currently being served by ULA.

Rocket Lab

Rocket Lab has conducted four launches in 2021 as of early September, three of them successful, using its two-stage Electron launch vehicle. The Electron first stage uses nine 3D-printed Rutherford engines that are powered by RP-1 and liquid oxygen. Its second stage uses a single Rutherford vacuum engine and Rocket Lab also employs a small kick stage with a monopropellant-powered motor to guide satellites into their final orbits.

Rocket Lab's first launch of 2021 in January, entitled "Another One Leaves The Crust," placed a single communications microsatellite in orbit for the European OHB Group. The second launch in March, entitled "They Go Up So Fast," consisted of seven satellites for various commercial and government partners, as well as the Photon Pathstone demonstrator spacecraft that will test various technologies ahead of the firm's forthcoming Moon mission for NASA and private mission to Venus.

"Running Out Of Toes," Rocket Lab's third launch in May, ended in failure after the Electron's second stage slewed out of control due to an ignition problem. The firm bounced back two months later with a successful launch in July. Dubbed "It's A Little Chile Up Here," the launch placed the Monolith communications test satellite in orbit for the Space Force's Space Test Program based out of Kirtland Air Force Base in New Mexico (hence the punning reference to chili peppers). Rocket Lab has planned a flurry of additional launches throughout the remainder of 2021.

Space X

On May 8, Space X set a milestone with the 10th successful flight of a Falcon 9 Block 5 first-stage booster (booster number B1051) from Cape Canaveral, Fla. The booster launched a group of Starlink satellites and completed its flight by landing on a drone ship in the Atlantic Ocean. The Falcon 9 is powered by nine Merlin engines, which burn RP-1 and liquid oxygen.

Space X completed the first successful high-altitude flight of its Starship prototype orbital vehicle on May 5. SN15 launched from Space X's Boca Chica facility in Texas, ascended to approximately 10 kilometers using three Raptor methane- and oxygen-fueled engines, reoriented to perform its "belly flop" reentry procedure, and then landed propulsively on its landing pad.

On June 17, Space X launched the GPS 3 SV-5 Sacagawea satellite for the Space Force on a reused Falcon 9 first-stage booster (booster number B1062) from Cape Canaveral Space Force Station, Fla. The booster had also launched GPS 3 SV-4 Neil Armstrong the previous November. The flight marked the first time that

a reused booster had been used for a National Security Space Launch mission.

Space X also conducted the first static fire test of its Super Heavy booster in Texas employing three Raptor engines on July 20. It next intends to conduct a nine-engine static test and will ultimately progress to a test flight using the booster's full complement of 30 Raptor engines. The flight will launch a Starship test vehicle on a suborbital trajectory from Texas to Hawaii later in 2021 or early 2022.

Most notably, billionaire Jared Isaacman privately chartered SpaceX's Dragon spacecraft to launch the first all-civilian crew on Sept. 16. The Inspiration4 Mission was the first to send civilians into orbit for a successful 3-day mission. The crew of four returned to Earth on Sept. 18. Inspriation4's mission represented "a new era for human spaceflight and exploration."

Virgin Galactic

On July 11, Virgin Galactic owner Richard Branson flew aboard the company's SpaceShip Two rocket plane in a suborbital flight that reached approximately 86 kilometers of altitude. SpaceShip Two was launched by the dual-fuselage WhiteKnightTwo carrier aircraft, christened VMS Eve, which took off from Spaceport America in New Mexico. Accompanied by five Virgin Galactic employees, Branson experienced a brief period of microgravity before the plane reentered the atmosphere and landed conventionally on a runway at the spaceport. The flight took approximately an hour from takeoff to landing. SpaceShip Two utilizes a hybrid rocket motor consisting of solid hydroxyl-terminated polybutadiene (HTPB) fuel and liquid nitrous oxide oxidizer. The vehicle is reusable and may be refueled by replacing the solid propellant stick and refilling the liquid oxidizer tanks. Virgin Galactic plans to begin regular space tourism flights in the near future pending Federal Aviation Administration approval.

Virgin Orbit

On January 17, Virgin Orbit completed its second demonstration of its LauncherOne rocket. The rocket launched from the Virgin Orbit 747 carrier aircraft, Cosmic Girl, over the Pacific Ocean off the coast of California, ignited its two-stage liquid-fuel motor powered by RP-1 and liquid oxygen, and ascended to orbit. Upon achieving orbit, it released 10 CubeSats as part of NASA's Launch Services Program (LSP) CubeSat Launch Initiative (CSLI).

On June 30, the company completed a second orbital launch, dubbed "Tubular Bells: Part 1," with its Launcher- One rocket that carried seven CubeSats into orbit: four for the Space Force's Space Test Program, one for the Royal Netherlands Air Force, and two for the Polish firm SatRevolution.

Two other U.S. companies of note, Firefly Aerospace Inc. (Cedar Park, Texas) and Astra Space, Inc. (Alameda, Calif.) also experienced launch activities, neither of which were fully successful. However, valuable data and launch operations experience was gained which will surely benefit both companies in their next attempts.

Firefly

Firefly attempted its first launch on Sept. 2, 2021 out of Vandenberg Space Force Base. They timed their T0 to occur right when their launch window opened up at 6:00 pm PDT, giving them a 5-hour opportunity to launch. Shortly before T-0 sec, a launch abort signal was given, thus terminating the first launch attempt. Firefly was able to assess their data and made a 2nd attempt within the hour. At approximately 6:59 pm PDT, all four Reaver engines ignited and Alpha successfully cleared the tower. At approximately T+15 sec, one of the engines shut down prematurely, however Alpha 001 continued with three remaining engines, albeit a bit slower than expected. Alpha 001 did not reach Supersonic speed until after Maximum Dynamic Pressure (Max Q). Shortly after the vehicle attained supersonic speed, the vehicle started to tip over on itself to the right and then back to its left. Shortly after that, the range sent a command to terminate the flight. Alpha 001 flew for approximately 150 seconds.

Firefly is in a middle of a failure investigation and is actively building up Alpha 002. Trying to keep a positive attitude on the first launch attempt, it was billed as a test flight and Firefly did collect a trove of flight data which will undoubtedly be useful for future flights.

Astra Space

On August 28th, Astra Space made its first commercial launch of their "Rocket 3.3" Launch vehicle, (LV0006). The launch was out of Kodiak, Alaska. The booster features five engines, one of which shut down immediately at launch. Viewing the video, the launch vehicle drifted laterally for several meters before ascending. The vehicle reached an altitude of approximately 50 km before the range ordered engine shut down at T+148 sec (the vehicle was not within its proscribed trajectory). Statements from Astra indicate that much valuable data was gathered and is being analyzed. Astra is planning for two more launches in October and December 2021: one for the Space Force and one for a commercial customer. The company's failure investigation into LV0006 will undoubtedly help improve their future LV's.

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