

JANNAF

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

NEWS

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Modeling and Simulation, Spacecraft Propulsion, Liquid Propulsion to Headline JANNAF Meeting

The December 2016 JANNAF Meeting in Phoenix, Ariz., will feature a keynote address by Jeffrey M. Hanley, Principal Director for Human Exploration and Space Flight, NASA and Civil Space Division of the Aerospace Corporation in Houston, Texas. Hanley will speak about the challenges that are shaping the future of space policy as the 50th anniversary of the Apollo 11 moon mission approaches during the first term of the next U.S. President.

The meeting will also feature the Programmatic Industrial Base Committee, which will be holding a specialist session that will highlight how modern technology and the next-generation workforce are changing the way that the propulsion industrial base is designing and producing rocket propulsion systems, including utilizing additive manufacturing.

Additionally, the December 2016 JANNAF meeting will host the 11th Modeling and Simulation Subcommittee (MSS) meeting, which is holding a plenary presentation by Dr. Ephraim Washburn from Naval Air Warfare Center Weapons Division. Dr.



Mr. Jeffrey M. Hanley, Principal Director for Human Exploration and Space Flight, NASA and Civil Space Division of the Aerospace Corporation in Houston, Texas, will discuss the challenges that will shape the future of space policy during the first term of the next president in his keynote address at the JANNAF meeting in Phoenix, Arizona.

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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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TECHNICAL INQUIRIES

- Data on nitrile rubber property degradation for long-term storage at elevated temperatures with exposure to air (Req. 28232)
- Information on HPLC or IC methods for determination of amide content in 2-(5-Cyanotetrazolato)Pentammine Cobalt(III) Perchlorate (BNCP) (Req. 28117)
- Sensitivity, impact (ERL/BOE), friction (Joules), VTS, and shock data for lead azide, lead styphnate, and RDX (Req. 28096)

BIBLIOGRAPHIC INQUIRIES

- Collection of reports related to the Scaled Composites accident in July 2007 (Req. 28221)
- Performance tailoring of extruded double-base propellants. Topics included I_{sp} modification, mechanical properties, sensitivity, etc. (Req. 28089) and noncompositional effects on double-base propellant performance. (Req. 27981)
- Literature on self-ignition or detonation of LOX-RP pools (Req. 28135)

RECENT JANNAF DOCUMENTS

- May 2016 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 Meeting, Phoenix, Arizona... *continued from page 1*

Ephraim will be discussing increased fidelity to system level calculations. The MSS will also be holding a specialist session to present a recent publication on advances in simulation credibility. For more information on this publication, please see the article on page 9.

Other subcommittees meeting in December include Liquid Propulsion (LPS), and Spacecraft Propulsion (SPS). The LPS is hosting a panel discussion on the future of liquid rocket engines in the U.S. and the SPS will feature a talk by Carl Engelbrecht of the Johns Hopkins University Applied Physics Laboratory on lessons learned in interplanetary propulsion; as well as a separate workshop on an electric propulsion program.

The December JANNAF meeting will be held Dec. 5-8 2016, at the Hyatt Regency Phoenix, which is located downtown. The chair of the meeting will be Dr. Michael D. Watson from NASA Marshall Space Flight Center. For additional information about the JANNAF meeting, please visit <https://www.jannaf.org/mtgs/2016Dec/pages/index.html>.



Dr. Michael D. Watson, NASA Marshall Space Flight Center, will chair the JANNAF meeting in Phoenix, Ariz.

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In Memorium

On July 31, 2016, Dr. Kenneth “Ken” Kuan-Yun Kuo passed away due to natural causes in State College, Pennsylvania at the age of 76. Ken Kuo was well-known within the propulsion and energetics community, having published and lectured extensively on propulsion, combustion, and energetics topics during his lengthy career. He founded the High Pressure Combustion Laboratory at the Pennsylvania State University and served as its director for 39 years until his retirement in 2011. The same year, Dr. Kuo received lifetime achievement awards from both JANNAF and the American Institute of Aeronautics and Astronautics (AIAA), and he was named a Ballistics Science Fellow by the International Ballistics Society in 2014. Previously, he had been named a fellow of the AIAA and the American Society for Mechanical Engineering (ASME).

After immigrating to the U.S. from Taiwan in the early 1960s, Ken Kuo received his M.S. in mechanical engineering from the University of California, Berkeley, in 1964. He went on to earn a Ph.D. in aerospace and mechanical sciences from Princeton University in 1971, authoring a dissertation entitled, “Theory of Flame Front Propagation in Porous Propellant Charges Under Confinement.” As a professor of mechanical engineering and director of the High Pressure Combustion Laboratory at Penn State, Dr. Kuo assumed a leadership role in more than 100 research projects that included such topics as characterizing and diagnosing the combustion behavior of nano-sized energetic additives in solid rocket fuels. He directed the research of more than 110 graduate students in the fields of combustion and propulsion and authored two seminal textbooks, in addition to 420 journal articles, book chapters, and conference presentations, for which he received numerous Best Paper awards from AIAA and JANNAF.

Dr. Kuo was born in Kunming, China, on December 17, 1939. He enjoyed travel, food, music, and the company of good friends and family. He possessed a lifelong interest in learning and education. After his



Dr. Kenneth Kuan-Yun Kuo (1939-2016)

retirement from Penn State, he and his wife, Olivia, endowed two Early Career Professorships in the Department of Mechanical and Nuclear Engineering in order to promote research in the fields of combustion and propulsion and encourage promising scholars to join the engineering faculty. Ken Kuo is survived by his wife of fifty-one years, two daughters, Phyllis Hinkle and Angela Kuo, their families, and two grandchildren, Esa and Tate. He is also survived by his sister, Katherine Lu, and her family.

JANNAF News is seeking short technical articles for future editions.

All articles must be Distribution Statement A / Publicly Releasable.

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

***Managing Editor Benjamin Schwantes at
BSchwantes@erg.jhu.edu***

In Memorium

Dr. Richard Vance Cartwright passed away on January 28, 2016, in Columbia, Maryland, at the age of 74. Dr. Cartwright earned a B.S. in chemistry from the Carnegie Institute of Technology in Pittsburgh (now Carnegie Mellon University) and a Ph.D. in organic chemistry from the Massachusetts Institute of Technology (MIT) with a 1967 dissertation entitled, "Use of substituent effects to infer the structure of the transition state for general acid-catalyzed enolization of ketones." Dr. Cartwright worked with numerous firms in the propellants, explosives, and pyrotechnics (PET) industry, and held research and development positions with Hercules, Princeton Combustion Research Laboratory (PCRL), and General Dynamics Armament and Technical Support. He joined the Chemical Propulsion Information Analysis Center (CPIAC) (now the Energetics Research Group (ERG)) at the Johns Hopkins University in 2006 as a senior staff scientist and research engineer. Dr. Cartwright was active in the

JANNAF community and supported the JANNAF Safety & Environmental Protection Subcommittee (S&EPS) through his work at CPIAC. He also authored many technical papers for professional journals on solid and liquid gun propellants and received 11 patents for technologies related to both defense and non-defense PET applications such as propellant-actuated inflation systems (i.e. air bags).



Dr. Richard V. Cartwright (1941-2016)

Dr. Cartwright was born on October 15, 1941, in Rochester, New York. He had a love for religious music and ministered in that capacity in 17 churches in eight states. He is survived by his wife of 50 years, Sallie Cartwright, and his daughter Merrie and her family.

In Memorium

On February 12, 2016, Dr. Rodney "Rod" Lee Willer succumbed to bladder cancer in Gulfport, Mississippi, at the age of 68. Rod Willer was an active member of the JANNAF community and contributed significantly to the fields of propulsion and energetics during his nearly forty-year career. He authored many papers and was awarded numerous patents for his work on energetic binders and monomers, propellant formulation, polycyclic nitramines, and energetic cubyl compounds. He also developed a new process for manufacturing hydroxyl ammonium nitrate. Dr. Willer earned his Ph.D. in chemistry at the University of North Carolina in 1976, authoring a dissertation entitled "Conformation Analysis and Carbon-13 NMR of Thianes and 1-Methylthianium Salts" and later held a postdoctoral position at Michigan State University. He began his career as a research

chemist at the China Lake Naval Weapons Center (now the Naval Air Weapons Station China Lake) and then as a senior scientist for Thiokol. He later served as technical director for Gaylord Chemical Corporation, managed the Chemical Division of Sloss Industries, and again served as a research chemist for Fluorochem, Inc. Finally, he received an appointment as a research scientist in the School of Polymers and High Performance Materials at the University of Southern Mississippi in Hattiesburg.

Rod Willer was born on November 27, 1948, in Albany, Oregon, to Lt. Col. James E. Willer and Dorothy Chilton Willer. He developed a love of the outdoors and devoted his free time to activities such as water skiing and rock climbing. He also had a passion for sports cars and power boats. Dr. Willer was preceded in death by his brother, Capt. Lonnie E. Willer, and is survived by siblings Col. Clinton W. Willer and Yvonne Marion Evans.

JANNAF Member and Former SpaceX VP Speaks at Johns Hopkins University

JANNAF member Jeff Thornburg, founder of the engineering technology development company, Interstellar Technologies, LLC, spoke about ways in which government and industry can work together to fast track innovation in space exploration at the Johns Hopkins University's Whiting School of Engineering on Sept. 21, 2016.

Thornburg spent much of his speech discussing his experiences while working at SpaceX and shared his observations about how quickly technology development progressed during his time as Vice President of Propulsion Engineering.

“You have to push the paradigms. In development you have to push as far as you can get away with and it should be ok to do that”

“Don’t believe anything anybody tells you about schedules and budgets. It’s really about progress and development,” Thornburg said. “You have to push the paradigms. In development you have to push as far as you can get away with and it should be ok to do that.”

Showing videos of several successful launches at SpaceX, Thornburg talked about how hard all the employees worked to make each launch a success. “Every launch is a single emotional event. It’s like birthing a baby every launch, every single time,” he stated of the enthusiasm seen by the staff at SpaceX in the videos.

Thornburg shared an anecdote about his first phone call with SpaceX founder Elon Musk who was interested in working with him in 2011. Not knowing who Musk was at the time, Thornburg told Musk’s assistant that he would have to call him back after he gave his daughter a bath and put her to bed. Thornburg ended up taking the job at SpaceX and staying for five years before leaving to start his own company, Interstellar Technologies, LLC. Prior to SpaceX,



Jeff Thornburg, Interstellar Technologies, LLC, speaks at the Johns Hopkins University's Whiting School of Engineering in a talk sponsored by the Commercial and Government Program Office.

Thornburg worked in both government and industry, giving him insight into how the two realms interact with each other in the field of space exploration.

“The sky is the limit, I want to see us move faster because I want to see the cool stuff happen before I’m 80”

Thornburg stated that he would like to see more collaboration between government and industry and saw a pressing need for fast tracking innovation. “The sky is the limit,” he said. “I want to see us move faster because I want to see the cool stuff happen before I’m 80.”

Thornburg’s speech was the first in a planned series of speeches by members of the community focusing on space research. The speaker series is sponsored by the Commercial and Government Program Office (CGPO) at Johns Hopkins University. CGPO’s next speech will be given by Chris Singer, NASA Deputy Chief Engineer, on Nov. 9. All are welcome to attend.

Reviewing the History of Scramjet Propulsion Development at the 2016 Spring JANNAF Meeting

The fascinating, complex, and sometimes frustrating development history of scramjet propulsion since the Second World War was the focus of an afternoon specialist session at the Spring 2016 JANNAF Meeting. Chaired by Dr. Richard L. Gaffney (NASA Langley Research Center), panelists Dr. David M. Van Wie (The Johns Hopkins University Applied Physics Laboratory), Dr. Lou Povinelli (NASA Glenn Research Center), Dr. Joe Schetz (Virginia Tech University), Dr. John I. Erdos (MIRA Facilities, LLC), Mr. Robert A. Mercier (Air Force Research Laboratory, WPAFB), Mr. Earl H. Andrews (NASA Langley Research Center, Retired), and Dr. Mark J. Lewis (IDA Science and Technology Policy Institute) discussed their own contributions to the hypersonic propulsion field, as well as the broader history of scramjet technology development in the United States from the 1940s through the present. Dr. Mark Lewis also reviewed the current state of hypersonic research in the U.S. and offered recommendations for future scramjet research and development efforts.

The scramjet concept emerged out of research on ramjet propulsion conducted by various groups in the 1940s and 1950s including the Johns Hopkins Applied Physics Laboratory (APL) and the NASA Langley Research Center. Growing interest in high-speed, long range, airbreathing missiles by the postwar U.S. military led to further theoretical and experimental research into ramjet combustion at supersonic speeds. One of the proponents of hypersonic propulsion, Italian immigrant Antonio Ferri, conducted research at NASA Langley in the 1950s and then founded General Applied Science Laboratories, Inc. (GASL), a key center for work on scramjet research and technology development from the 1960s through the present. Research

into supersonic combustion at hypersonic speeds necessitated specialized air tunnels and various other testing rigs that could simulate Mach 5+ test conditions. These were constructed at APL, NASA Langley, GASL, NASA Lewis/Glenn, Virginia Tech, and elsewhere. In the 1980s, NASA and the DoD proposed the National Aerospace Plane (NASP) project, conceived as a single-stage-to-orbit technology demonstrator. The project was eventually cancelled in 1993 after it became clear that current technology was insufficient to meet the expanding requirements placed on the NASP project. Following the project's cancellation, researchers at NASA and the Air Force continued working on scramjets at a smaller scale. The Hyper-X, X-51, and HIFiRE programs focused on incremental flight testing of scramjet engines and helped to accumulate valuable data on inlet configuration, combustion of hydrocarbon and hydrogen fuels, mode transition, and other necessary aspects of scramjet propulsion.

The panelists at the specialist session shared their first-hand observations about these developments in scramjet propulsion. Dr. Van Wie focused on scramjet work at the JHU Applied Physics Lab and highlighted the lab's theoretical work, as well as its investigations of materials that could handle the heat and stresses of supersonic combustion. Dr. Povinelli discussed the on-again, off-again scramjet research efforts conducted at NASA Lewis/Glenn Research Center. Dr. Schetz described his involvement in scramjet work, first at GASL and later at the University of Maryland, APL, and Virginia Tech. Dr. Erdos touched on Antonio Ferri's work at GASL and the lab's later research efforts on scramjet propulsion in conjunction with NASA and other partners. Mr. Mercier discussed the Air Force's work on hypersonic propulsion and the successes of the X-51 program. Mr. Andrews presented a detailed chronology of scramjet research at NASA Langley

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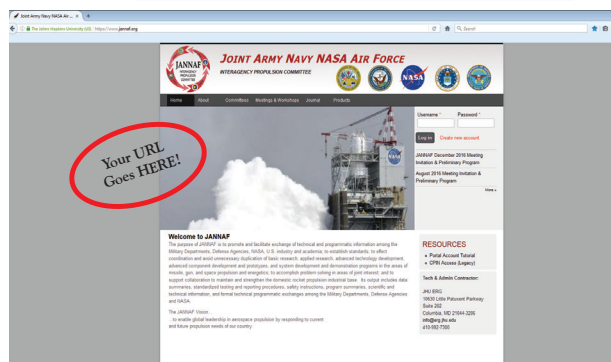
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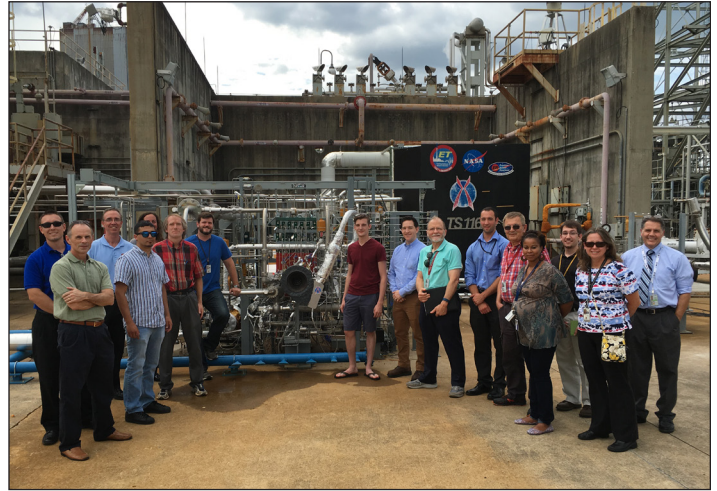


Liquid Propulsion Subcommittee Advanced Materials Panel Hosts 2nd Additive Manufacturing for Propulsion Applications Technical Interchange Meeting

The Advanced Materials Panel of the Liquid Propulsion Subcommittee (LPS) teamed up with NASA Marshall Space Flight Center (MSFC) and the National Institute for Rocket Propulsion Systems (NIRPS) to host the second Technical Interchange Meeting (TIM) on Additive Manufacturing (AM) for Propulsion Applications in Huntsville, Ala., from Aug. 23–25, 2016. Since two years have passed since the last TIM on AM, the intent of the August 2016 meeting was to offer the technical community the opportunity to present and discuss relevant work in science, technology and manufacturing associated with the application of AM in critical propulsion components, as well as network with their fellow participants. Presentations were generally focused on the liquid propulsion applications, but the Call For Presentations included topics ranging from Designing for AM to Post Build Processing, Finishing, and Inspection.

Planning for the second TIM began almost immediately after the first additive manufacturing TIM, held Sept. 5–7, 2014. Elizabeth Robertson of NASA MSFC and Alison Park of Aerojet Rocketdyne, Canoga Park, led the planning efforts. They, along with the planning committee, sought to cover a wide range of topics related to AM. These included: Component Fabrication and Testing; Additive Manufacturing Techniques and Machines; Post Build Processing, Finishing and Inspection; Materials; Design for Additive Manufacturing; Modeling and Simulation; Process Qualification and Specification; Process Analysis, Sensing, and Control, Non-Destructive Evaluation; Special Topics; and Future Needs. The Future Needs topic was covered by a select panel of speakers who presented senior perspectives related to government, industry, and public-private partnerships.

Two years ago, the theme of the first AM TIM could have been described as “Wow, Look what we can do with AM!” For the second TIM, the engineering theme shifted to “Hum, I wonder why it did that?” In other words, presentations were more oriented toward the science of design of the AM process and methods for improving the quality of the final manufactured part and preventing flaws or defects. Studies of the effects of



AM TIM participants led by Andrew Hanks examine the Additive Manufacturing Rocket Engine test bed at NASA MSFC.

surface roughness and ways to design the components to accept the typical AM finished surface were also described and discussed. Modeling and Simulation efforts to anchor Computational Fluid Dynamics models within the realities and limitations of AM were indicative of the engineering focus now appearing in AM work. Advances in the capabilities of AM machines have allowed the Process Control and Modeling communities to begin applying their areas of investigation to prevent flaws and improve the processing of the AM parts. In all, the second AM TIM provided a much-needed overview of the ways in which additive manufacturing can support propulsion applications.

**The Johns Hopkins University
CGPO Speaker Series**

**Christopher Singer
NASA Deputy Chief Engineer**

**Nov. 9, 2016
3:00-5:00PM**

**Hackerman Hall, Room 320
The Johns Hopkins University
3101 Wyman Park DR
Baltimore, MD 21218**

JANNAF holds 63rd Propulsion Meeting near NASA LaRC as NASA celebrates 100 years

As NASA celebrated its 100th anniversary, the 63rd JANNAF Propulsion Meeting took place in Newport News, Virginia, near the NASA Langley Research Center (LaRC). The center's director, Dr. David E. Bowles, offered welcoming remarks on behalf of NASA at the keynote address and awards ceremony. A tour of LaRC was also given to interested attendees at the conclusion of the meeting.

Karen Burrows, Executive Director of the Naval Ordnance Safety and Security Activity (NOSSA) and the Deputy for Weapons Safety, Naval Sea Systems Command (NAVSEASYS COM) delivered an engaging and educational overview of U.S. naval history and noteworthy incidents and catastrophic mishaps that led to improvements in the Naval Ordnance Safety Program. Burrows touched on incidents that occurred on the USS Thresher, the USS Oriskany, the USS Forestal, and at the Naval Ammunition Depot in Lake Denmark, New Jersey, which led to the creation of the Department of Defense Explosives Safety Board (DDESB). Her talk culminated with the opening of Naval Ordnance Safety and Security Activity (NOSSA), which was established in 1999 when it was decided that the Navy's weapons and explosives ordnance safety organizations needed to be housed under one roof.

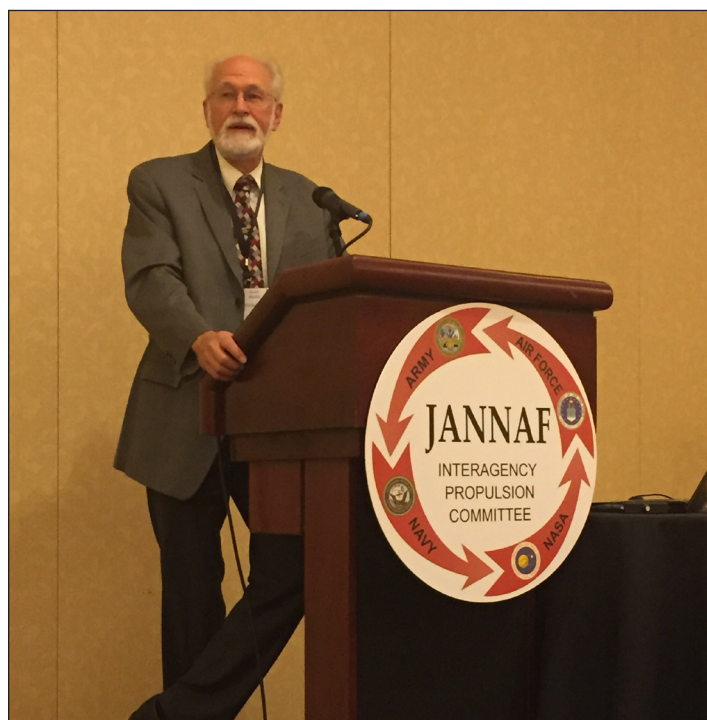
Despite major achievements in naval safety and security, Burrows repeatedly stressed the need for continued vigilance. "Even though we have come a very long way in developing newer and more powerful yet more insensitive energetic materials and weapons, we are reminded that the testing protocols that we have developed over the last few decades and the results of these tests often can provide previews of the responses we can see in tomorrow's incidents," Burrows stated.

The meeting also hosted the Programmatic Industrial Base, the 47th Combustion Subcommittee, the 35th Air-breathing Propulsion Subcommittee, the 35th Exhaust Plume Signatures Subcommittee, the 29th Propulsion Systems Hazards Subcommittee, and the Joint Subcommittee Meeting. During the meeting, a special edition of



Keynote speaker Karen Burrows, Executive Director of the Naval Ordnance Safety and Security Activity (NOSSA) and the Deputy for Weapons Safety, Naval Sea Systems Command (NAVSEASYS COM).

the *JANNAF Journal* Volume 6, Issue 2 was distributed to attendees. A specialist session was held on the history of scramjet propulsion development. Please see page 7 for more information on the specialist session.



Outgoing JANNAF Technical Executive Committee Chairman Stuart Blashill speaks at the May JANNAF Meeting.

Modeling & Simulation Subcommittee to Release Report on Advances in Simulation Credibility

Quantified simulation credibility—establishing accuracy in terms of uncertainty—has been the principal challenge in the field of numerical simulation technology since its inception a century ago. Beginning in 1980, the significance of simulation credibility has continuously increased as numerical simulations have become ubiquitous in an increasing number of fields such as science and engineering, technology development, product acquisition, warfare, risk assessment, and “what if” studies. Simulation verification, simulation validation, uncertainty propagation, uncertainty quantification, and uncertainty aggression are the key processes used to quantify numerical, model, input, referent and input, and output uncertainty, respectively.

In 2007, Dr. Unmeel Mehta (NASAARC) and Dr. Dean Eklund (AFRL WPAFB), co-chairs of the Simulation Credibility—Uncertainty, Verification, Validation and Risk—Panel, began a voluntary effort to develop a simulation credibility guide to describe and demonstrate state-of-the-art approaches for simulation verification, simulation validation, and uncertainty quantification. Dr. Mehta took the lead to accomplish this endeavor. Dr. Eklund and a team of three colleagues—Dr. Vicente Romero (Sandia National Laboratories), Jeffrey Pearce

(United Technology Corporation), and Nicholas Keim (The Johns Hopkins University)—assisted and advised.

Over the last decade, numerous workshops were held to identify specialists in different aspects of simulation credibility, discuss advances in the aforementioned processes, highlight key modeling and simulation issues related to airbreathing hypersonic propulsion and liquid and solid rocket propulsion, review proposed chapters necessary to capture and describe the current state of knowledge, and publish the Simulation Credibility Guide. Multiple JANNAF subcommittees, including APS, LPS, and S&MBS participated either directly or indirectly through their communities and voluntary contributions to this effort.

“Simulation Credibility: Advances in Verification, Validation, and Uncertainty Quantification” is the result of these efforts and comprises an introduction, 14 chapters and over 500 pages dedicated to establishing and quantifying the credibility of continuum physics simulations.

A specialist session will be held on Dec. 7, 2016 at the JANNAF PIB / 11th MSS / 9th LPS/ 8th SPS Joint Meeting, Dec. 5–9, 2016, where contributing authors will present an overview of their chapters. The document will be available from JHU WSE ERG as a JANNAF/GL—2016–0001 and from NASA STI as a NASA Technical Publication before Thanksgiving 2016.

64th JPM / PIB / 11th MSS / 9th LPS / 8th SPS

Dec. 5–9, 2016

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Phoenix, Ariz.

Questions

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Scramjet Specialist Session ... *continued from page 7*

and discussed the research facility's involvement with hypersonic projects including NASP and later Hyper-X. Lastly, Dr. Lewis focused on some of the lessons learned by the scramjet research community regarding development of viable scramjet-powered vehicles and stressed the importance of maintaining

institutional knowledge and pursuing multiple developmental flow paths. In all, the scramjet specialist session highlighted the significant advances in hypersonic propulsion over the past sixty years and offered a vision of the technology's development trajectory over the next generation.



Participants in Networking Night at the May JANNAF Meeting.

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