

JANNAF

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



FALL 2012

NEWS

Volume 1, Issue 1 Released November 21, 2012

A Note from the CPIAC Team

Welcome to the JANNAF News

All,

Welcome to the inaugural issue of *JANNAF News*, our biannual newsletter about all JANNAF matters. As many of you know, due to some restricting of efforts here at the Chemical Propulsion Information Analysis Center (CPIAC), the long-running *CPIAC Bulletin* was retired after 37 years of dedicated service.

It is our great pleasure to reopen and revitalize this essential line of communication and current awareness with our JANNAF audience. Inside you will find many familiar subjects (and faces) as well as some new items designed to better keep you informed of the achievements and challenges that highlight both the success of our community, and the continued need for its vitality.

As we strive to transform to accommodate our dynamic environment, we rely heavily on feedback from our readership. If you have any suggestions, ideas, or comments, we welcome hearing them.

Sincerely,

The CPIAC Team



» Upcoming
JANNAF
Meetings

PAGE 3,16

» Recent
JANNAF
Meeting

PAGE 6

» JANNAF
Journal

PAGE 15

» Products,
Publications,
& Packages

PAGE 17

» JANNAF
Executive
Committee

PAGE 18

» Calendar of
JANNAF
Meetings

PAGE 20



Editor: Nicole M. Miklus
410-992-7303, ext. 227
nmiklus@cpiac.jhu.edu

CPIAC Deputy Director: Peter E. Zeender
The Johns Hopkins University/CPIAC
10630 Little Patuxent Parkway, Suite 202
Columbia, Maryland 21044-3286
<http://www.cpiac.jhu.edu>
Fax: 410-730-4969

The Chemical Propulsion Information Analysis Center (CPIAC), a DoD Information Analysis Center, is sponsored by the Defense Technical Information Center (DTIC) and 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.

CPIAC is responsible for the acquisition, compilation, analysis, and dissemination of information and data relevant to chemical, electric, and nuclear propulsion technology. A fee commensurate with CPIAC products and services is charged to subscribers, who must meet security and need-to-know requirements.

JANNAF News is available free of charge to the propulsion community. Reproduction of *JANNAF News* articles is permissible, with attribution. Neither the U.S. Government, CPIAC, nor any person acting on their behalf, assumes any liability resulting from the use or publication of the information contained in this document, or warrants that such use or publication of the information contained in this document will be free from privately owned rights.

Copyright © 2012 The Johns Hopkins University
No copyright is claimed in works of the
U.S. Government.

The content of *JANNAF News* approved for public
release; distribution is unlimited.

*CPIAC is a JANNAF- and DTIC-sponsored DoD
Information Analysis Center operated by The Johns
Hopkins University Whiting School of Engineering
under contract W91QUZ-05-D-0003.*

CPIAC's Technical/Bibliographic Inquiry Service

CPIAC offers a variety of services to its subscribers, including responses to technical/bibliographic inquiries. Answers are usually provided within three working days, in the form of telephoned, faxed, electronic, or written technical summaries. Customers are provided with copies of JANNAF papers, excerpts from technical reports, bibliographies of pertinent literature, names of recognized experts, propellant/ingredient data sheets, computer programs, and/or theoretical performance calculations. The CPIAC staff responds to nearly 800 inquiries per year, from over 180 customer organizations. For further information, please contact Nick Keim by email to nkeim@cpiac.jhu.edu. Representative recent inquiries include:

TECHNICAL INQUIRIES

- PBXN-103, PBXN-105, and PBXN-111 Navy explosive aging, qualification, and characterization (Req. 27822)
- Determination of manufacturing dates for ZUNI, Super ZUNI, Nike Hercules Booster, Mighty Mouse, and Sprint 2nd stage motors (Req. 27824)
- Atlas V SRB propellant composition (Req. 27769)
- Information on Nitrous Oxide Fuel Blends (NOFB) properties and performance (Req. 27757)

BIBLIOGRAPHIC INQUIRIES

- Moisture prevention for ammonium nitrate propellants (Req. 27884)
- Hydroxylammonium Nitrate (HAN) production, use, and applications in propulsion or commercial energetics (Req. 27687)
- Fire-in-the-hole (FIH or "hot") staging method (Req. 27662)

JANNAF To Meet in Monterey in December

45th Combustion Subcommittee (CS)/33rd Airbreathing Propulsion (APS)/33rd Exhaust Plume and Signatures (EPSS)/27th Propulsion Systems Hazards Joint Subcommittee Meeting

December 3-6, 2012

The Hyatt Regency Monterey is the site of the 45th Combustion, 33rd Airbreathing Propulsion, 33rd Exhaust Plume and Signatures, and 27th Propulsion Systems Hazards Joint Subcommittee Meeting. The meeting will be held from December 3-6, 2012. There are 49 technical sessions, 7 workshops, and 2 specialist sessions currently scheduled. Classified sessions will take place at the Naval Postgraduate School.

The keynote address, entitled “Blue Origin’s Hydrogen/Oxygen Engine Development Program,” will be delivered by Mr. Curtis Johnson of Blue Origin, LLC, on Tuesday, December 4th, from 8:00-10:00 a.m. Mr. Johnson joined Blue Origin, LLC in 2007 to lead the development of the BE-3 hydrogen/oxygen liquid rocket engine. His presentation will review significant accomplishments to date, and then focus on the development of a 100,000 lbf hydrogen/oxygen engine.

Michael K. Weiderhold, of New World Solutions, will present a classified briefing entitled, “New Directions in Persistent GEOINT Remote Sensing,” at the Naval Postgraduate School’s ME Auditorium on Wednesday, December 5th, from 8:00-9:00 a.m. The address will describe the technical aspects of new and planned persistent GEOINT remote sensing systems and the opportunities to better characterize energetic targets. Mr. Weiderhold will discuss how these systems might contribute to the community’s need to understand the application of combustion-related technologies throughout the world, and identify challenges that must be collectively dealt with to more fully capitalize on the capabilities of these resources.

The Airbreathing Propulsion Subcommittee (APS) sessions will discuss technical problems and issues associated with airbreathing propulsion systems, for applications to missiles, launch vehicles, aerospace planes, and remotely piloted vehicles. Session topics include characterization of system performance, engine cycle analysis and testing, engine design, engine/airframe integration, thermal management, fluid and structural mechanics, advanced engine structures and materials, fuel control systems, and characterization of advanced airbreathing fuels. APS has six active panels meeting in December:

- The *Engine Testing & Validation Panel* is working three separate tasks which will provide updates to CPIAC Pub 710. These tasks are: 1) scramjet engine test standards: recommended practices, guidelines, and standards for scramjet propulsion; 2) scramjet test medium effects: recommended practices, guidelines, and standards for evaluating scramjet propulsion systems in ground facilities with various levels of deviation from clean air; and 3) large-scale engine development: recommend practices, guidelines, and standards for developing to TRL 6 scramjet and scramjet-based combined cycle engines whose scale exceeds that of the available infrastructure for ground test at full scale.
- The *Component-Level & Physical Modeling Panel* is concerned with the standardization of analysis procedures for valid and useful modeling and simulation associated with ramjet, scramjet, and combined cycle engines.



The Hyatt Regency Monterey (left) and Naval Postgraduate School (right)

(continued on page 4)

JANNAF To Meet in Monterey...continued from page 3

The panel is also focused on standardizing modeling and simulation nomenclature, protocol, and operational practices; cataloging and evaluating archival data; and assisting users with JANNAF-sponsored models and simulations.

- The *Fuels Panel* is tasked to develop fuel specifications based on systems requirements and capabilities, determine fuel property implications on system and component performance, and standardize fuel characterization and test procedures. Fuels include liquids, slurries, solids, cryogenics, fuel-rich gas generator effluents, and special fuels for combined cycle engines.
- The *Structures & Materials Panel* is concerned with the development of analytical and experimental techniques and solutions to problems in the structures and materials of ramjet, scramjet, and combined cycle engines and their installations. This includes evaluation of insulators, ablators, bonding systems, and case materials; design of actively cooled structures; routing and management of coolant streams; and other issues relating to the structures and material systems of an aerospace vehicle propulsion system.
- The *Advanced Engine Cycle Panel* is working on: 1) developing comprehensive standards, guidelines and best practices for pressure gain combustion propulsion and power generation systems, with initial recommendations in the form of station designations, nomenclature, modeling/analytical tools, and “minimal” experiments for generic engine configurations; 2) pursuing activities aimed at identifying the accuracy of engine performance predictions tools for scramjet operation; and 3) defining specific needs and approaches to improve performance prediction capability, specifically in the areas of combined cycle engine interactions and prediction of dynamic characteristics of combined cycle engines.
- The *Active Combustion Control Panel* is interested in advanced active combustion control technology for gas turbines, rockets, and ramjets. Combustion control includes issues such as NO_x control, pattern factor control, blowoff control, combustion dynamics control, and mode transition in combined cycle, launch-vehicle propulsion systems, and combustion control on flight systems, such as under the UEET program.

The Combustion Subcommittee (CS) meeting will include sessions on chemical combustion phenomena occurring within the interior of guns and combustors of solid, liquid, and airbreathing (including small or expendable turbojets) missile and space propulsion systems. Papers that will aid in developing design criteria to build efficient and stable combustion systems, and papers that will aid in synthesizing, interpreting, and validating current knowledge to make research and development results more useful to design engineers are also included. CS currently has four active panels meeting in conjunction with the conference:

- The *Kinetic and Related Aspects of Propellant Combustion Chemistry Panel* is developing a consensus on the modeling, diagnostics, and chemical kinetics of propellant combustion phenomena on a detailed chemical level, to improve the understanding of physical phenomena associated with airbreathing, gun, and rocket applications.
- The *Flow Field Diagnostics Panel* is exploring the current state-of-the-art in nonintrusive diagnostics and emerging diagnostic capabilities that can be made more readily available to the propulsion community with encouragement and support from the user (project manager) community.
- The *Reactive Materials Panel* is making more effective and efficient use of Reactive Materials (RMs) in weapons systems by exploring the important physics, creating basic and applied research tools, and developing/selecting candidate RMs.
- The *Fuels Properties & Kinetics Panel* is increasing the predictability of matching experimental data on ignition behavior or flame speeds for individual fuel compounds with “reasonable” sets of rate expressions. The ultimate aim is to produce a central information resource to serve as a depository of previous work on the chemical kinetics of the combustion of hydrocarbon fuels. The goals of the panel are to include models, with the chemical kinetic databases that have been proven along with and the experimental studies that have been used to verify the models.

(continued on page 5)

JANNAF To Meet in Monterey...continued from page 4

The Exhaust Plume and Signatures Subcommittee (EPSS) meeting will include sessions on the phenomena associated with the exhaust from rockets, ramjets, aircraft, space, and gun propulsion systems. These phenomena can be divided into three technical areas: plume flowfields, plume radiation, and a broad area incorporating other plume effects. Sessions will be held on the state-of-the-art in plume and base flowfield modeling and analysis as well as RF, microwave, and IR plume signature simulation and analysis—including new code developments, algorithms, and validation data. EPSS panels will be meeting in conjunction with the conference.

- The *EPSS Signatures Panel* (formerly the *Spectral and In-band Radiometric Imaging of Targets and Scenes (SPIRITS) Users Group*) promotes technical interchange among members of the Electro-Optical/Infrared (EO/IR) aircraft signature community from both government and industry. The panel will hold an aircraft signatures code users' group meeting with the developer of SPIRITS as an opportunity for discussion and collaboration on code uses and improvements.
- The *EPSS Collaborative Efforts Panel* focuses on updating and improving existing plume prediction models and initiates new model development utilizing state-of-the-art methods and technologies. This collaboration includes the legacy JANNAF-standard plume codes as well as the advanced next-generation tools for both plume flowfield and signature predictions. Experimental efforts are also pursued to provide the data for code validation across all application areas.

The Propulsion Systems Hazards Subcommittee (PSHS) meeting will address hazards and related technology areas for strategic missile, tactical missile, gun, and rocket propulsion systems. Papers are invited that: (1) address all aspects of vulnerability and survivability, loading and firing hazards of propulsion systems, and weapon systems safety; or (2) aid in synthesizing, interpreting, and validating current knowledge to make research and development results more useful to the design engineer. Meeting topics generally fall into two groups: (1) hazards evaluation and (2) hazards mitigation technology. PSHS has four active panels that will be meeting.

- The *Cookoff Hazards Technology Panel* seeks to identify scenarios in which exposure of munitions to high temperatures could result in violent reactions, and to develop technology to prevent or minimize the violence.
- The *Impact/Shock-Induced Reactions Panel* supports the standardization of methods for testing the response of munitions to shock or impact. The panel also seeks to identify scenarios in which impact or shock could result in violent reactions, and to develop technology to prevent or at least minimize the violence.
- The *IM Technology Panel* supports the documentation of previous IM technology development efforts in a summary form that scientists and engineers can reference and use in the planning and execution of current and future work.
- The *Safety and Hazard Classification Panel* supports the development of test methods for detection of unsafe conditions in production/transportation/storage of munitions, and the development of new hazard classification test methods and harmonized test methodologies consistent with DoD and NATO requirements.

Hotel rooms are available at the Hyatt Regency Monterey. For reservations, call 888-421-1442.

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

CS and APS: Mr. Ron Bates (rbates@cpiaac.jhu.edu/443-718-5008)

EPSS: Mr. Nick Keim (nkeim@cpiaac.jhu.edu/443-718-5005)

PSHS: Mr. Andy Taylor (ataylor@cpiaac.jhu.edu/410-992-7306)

For all other meeting-related matters, please contact Patricia Szybist (pats@jhu.edu/410-992-7302).

JANNAF Gathers in San Antonio for 59th Propulsion Meeting and Subcommittee Meetings

The JANNAF Propulsion Meeting (JPM) was held April 30-May 4, 2012, at the Grand Hyatt Riverwalk, in San Antonio, TX. Along with the JPM, the following subcommittees met:

- Structures and Mechanical Behavior Subcommittee (SMBS);
- Propellant and Explosives Development and Characterization Subcommittee (PEDCS);
- Rocket Nozzle Technology Subcommittee (RNTS); and
- Safety and Environmental Protection Subcommittee (SEPS).



Attendees check in at the registration table.

At this meeting, the RNTS held an “Advanced Thermal/ Structural Modeling of Carbon Cloth Phenolic” workshop. The SMBS held a “Space and Military Wireless Sensor Systems” workshop for the fifth time, with this meeting focusing on “User Integration Challenges for Wireless Sensor Systems.” The Propulsion Systems Hazards Subcommittee (PSHS) held a “Slow Cook-off Rate Determination” workshop and the Airbreathing Propulsion Subcommittee (APS) held its second “Pressure Gain Combustion” workshop.

397 attendees enjoyed a program featuring 1 keynote, 4 workshops, 4 specialist sessions, and 165 technical papers presented in 34 paper sessions. Additionally, 17 subcommittee panels met to discuss ongoing and new technical collaboration activities within the JANNAF community.

JANNAF SUBCOMMITTEES’ PANEL ACTIVITIES

SMBS

The SMBS panels are Material Properties and Characterization; Nondestructive Evaluation (NDE); Defect Evaluation; Service Life; and Structural Analysis.

The NDE Panel and the Defect Evaluation Panel (DEP) met jointly at the conference, resulting in good synergy between the two. The DEP discussed its “Guidelines for Rocket Motor Grain Defects Analysis” task. The NDE Panel indicated it would like to have a similar guideline for the NDE aspects that compliments the DEP guideline. The two panels plan to work together organizing a workshop that will discuss defects from detection, structural

Session chairs meet in the morning to review the day’s activities.

integrity evaluation, and service life impacts, to be held at the next SMBS conference.

The Structural Analysis Panel discussed its FEM Builder Users Group, Probabilistic Analysis Handbook, and Bondline Failure Criteria. The FEM Builders Users Group was assisting with a training session for FEM Builders scheduled during the summer of 2012. The writing of a Probabilistic Analysis Handbook is an ongoing task. A draft of the Bondline Failure Criteria has been reviewed by the panel members; the next phase is for the panel to merge the criteria into a revision for CPIAC Publication 612, “Guidelines for Determining Rocket Motor Grain Design Margins of Safety.”

The Material Properties and Characterization Panel reviewed a status update of recent activities. The Stress Relaxation test procedure task is estimated to be progressing towards transitioning into a Full Standard to be added to CPIAC Publication 21 (Pub 21), “Solid Propellant Mechanical Behavior Manual.” The previously completed Coefficient of Linear Thermal Expansion (CTE) Round Robin transitioned to Tentative Standard status. The draft CTE procedure will result in an addition to Pub 21 as Section 4.9.4. A Dynamic Mechanical Analysis (DMA) test method for characterization of viscoelastic stiffness in development is awaiting a NATO Standardization Agreement (STANAG) for the DMA and a round robin that a NATO committee is planning. STANAG procedures have been superseding United States defense standards (MIL-SPECs), however, since JANNAF procedures are more detailed and still needed even if

(continued on page 7)

JANNAF Gathers in San Antonio...*continued from page 6*

incorporated into a STANAG procedure, STANAGs could not supersede Pub 21 but may be incorporated into it.

At the Service Life Panel, the new service life requirements and goals that are increasing for both new and existing systems were discussed. These require improved predictive technologies and applications of health monitoring to service life assessment, including TEXCHEM. Also discussed was a task to update the guidelines for the use and acceptance of sensors in solid rocket motors, CPIAC Publication 724, "JANNAF Guidelines of Recommended Practices and Lessons Learned for Sensor Application in Solid Rocket Motors." Earlier in the week, the panel held "Space and Military Wireless Sensor Systems Workshop V: User Integration Challenges for Wireless Sensor Systems." The two-day workshop was a day and a half of presentations on integration challenges and a half day of combining what was learned to document answers to a series of questions. The questions addressed challenges to integrating sensor systems; obstacles and road blocks to overcome in integration and procurement of wireless sensing systems; approaches to solve and overcome issues; what is being measured; critical measurements and easy measurements; special sensing technologies the propulsion community would like to see developed; and data distribution/storage, uses, and safeguarding. A few overarching challenges revolve around communication, misunderstandings, and requirements. A tiger team was formed to assemble a collection of trade studies identifying the payoffs.

PEDCS

PEDCS panels include the Propellant and Explosive Process Engineering, Solid Propellant Ingredients and Formulations, Propellant and Explosive Surveillance and Aging, Liquid Propellants, and a joint Green Energetic Materials panel with SEPS.

The Propellant and Explosive Process Engineering Panel exists to promote awareness of processing issues for propellants and explosives associated with parameters such as mix viscosity, pot life, processing time requirements, and curing. Representatives of the Army, Navy, Air Force, and commercial industry attended the panel. The meeting discussed the panel's ongoing tasks and the relevant specialist sessions occurring at the conference. These included an informal discussion on hydroxyl-terminated polybutadiene (HTPB) variability, a "Thermochemistry of Selected Compounds" specialist session, and a "Status of Selected Propellant Ingredients" specialist session held jointly with the Solid Propellant Ingredient and Formulation Panel. The "Status of Selected Propellant Ingredients" session discussed the status of the following critical

materials: HTPB, Poly bd®, ammonium perchlorate, nitrate esters, nitramines, nitrocellulose, nano iron oxide, and glycidyl azide polymer. Based on attendance and the need for this session, another should be planned for the next PEDCS meeting. Topics featured in the discussion on HTPB variability included industry examples of HTPB variability within DOD programs and modifications to the HTPB manufacturing process.

The Solid Propellant Ingredients and Formulations Panel exists to provide tools for chemists and engineers who are involved in propellant formulation/optimization, and to increase awareness of related information already available. This panel's current task is the facilitation of propellant R&D, which is a driver for organizing the "Status of Selected Propellant Ingredients" specialist session with the Propellant and Explosive Process Engineering Panel.

A Guns and High Gas Output Devices Panel explored new ingredients and applications of existing ingredients for gun propellants and gas generants, and to address issues of propellant processing, storage, packaging, and shelf life. At this panel's meeting, the panel members chose to disband activities until a greater need and involvement from the community exist.

The Propellant and Explosive Surveillance and Aging Panel's mission is to promote improvement in the reliability and credibility of solid propellant aging investigations. One panel task is to seek information on the relationship between stress and strain characteristics and impact sensitivity. Another task is an evaluation of aging characterization test techniques. During this meeting, the panel was responsible for a joint meeting between panel members and the Joint Propellant Safety Surveillance Board (JPSSB), where the Army, Navy, Air Force, and USMC presented the current status of their respective surveillance programs. Future cooperation between JPSSB and this panel is extremely likely.

The Liquid Propellants Panel addresses needs for improvement in the production, storage, and deployment of liquid propellants, and the utilization of the most up-to-date knowledge of the properties of liquid propellants. A task to review and update the physical and chemical properties of hypergolic propellants is prompting the panel to compile data to update JHU/CPIAC's Liquid Propellants and Fuels Database.

RNTS

The RNTS panels are Nozzle Analysis and Modeling; Nozzle Design, Test and Evaluation; Processing Science and Materials; and Nozzle Control Systems. Two of these panels met during this meeting: Nozzle Analysis and Modeling, and Nozzle Design, Test, and Evaluation. A

(continued on page 8)

JANNAF Gathers in San Antonio...continued from page 7

major topic of conversation in the RNTS panels was nozzle material obsolescence.

RNTS held a one-day “Advanced Thermal/Structural Modeling of Carbon Cloth Phenolic” workshop. This workshop was the first of a series intended to facilitate development of an industry-accepted, physics-based, nonlinear, fully integrated, coupled structural and thermal analysis code for accurate prediction of the structural response of heated phenolic material used in ablative thermal protection systems. This initial workshop reviewed historical efforts from previous investigators and laid the groundwork for future workshops and the development of the advanced codes. An interagency code evaluation effort was initiated and will allow engineers and scientists to identify strengths and weaknesses in the analytical approaches they are currently using. Future workshops will be critical for developing, reviewing, and sharing advanced modeling approaches.

SEPS

Panels in the SEPS include Environmental Protection; Industrial Hygiene; Occupational Health & Toxicology; Demilitarization, Reclamation, and Reuse Technology; Range Safety and Atmospheric Modeling; and the joint Green Energetic Materials panel with PEDCS.

The joint PEDCS-SEPS Green Energetic Materials Panel and the SEPS Environmental Protection Panel met together during this conference due to the synergy between the two.

The Demilitarization, Reclamation, and Reuse Technology Panel discussed changing the focus of the panel to be design for demilitarization.

The Occupational Health & Toxicology panel is working on an addition to CPIAC Publication 394 (Pub 394), “Hazards of Chemical Rockets and Propellants.” A presentation on nitrate esters is scheduled for the next SEPS meeting, where that information may be used to further update Pub 394. A presentation on the toxicity of another nanocompound of military interest has been submitted for the next SEPS meeting. Pub 394 subscriptions are available online in the Chemical Propulsion Information Network (CPIN) and can be accessed using your CPIN account.

The Industrial Hygiene Panel discussed a new Air Force Research Laboratory funded development effort for the Chemical Hazard Analysis and Management Program (CHAMP). This tool will enable environmental health and safety management systems to review chemical inventory requests, perform hazard analysis, and offer first responders a way to quickly sort through a chemical inventory for the most hazardous materials. It will also allow sorting based

on health, fire, and reactivity values. The panel discussed collaborative National Institutes of Health (NIH) and National Library of Medicine (NLM) projects of interest to the DoD, and the integration of CHAMP with NLM databases, such as the Hazardous Substance Database (HSDB) and NIH’s new Chemical Hazards Emergency Medical Management (CHEMM) application.

KEYNOTE HIGHLIGHTS

Mr. Richard Matlock, Program Executive for Advanced Technology, presented a keynote address entitled, “Advanced Technology: Fueling the Next Generation Missile Defense System.” Mr. Matlock is leading the development of the next generation of cutting-edge missile defense technologies and proving their benefit to the warfighter through realistic experiments in relevant environments. Some of Mr. Matlock’s other senior executive assignments included the Program Director for the Ballistic Missile Defense System (BMDS) Kill Vehicles program, Program Director for Modeling and Simulation, and Technical Director for Kinetic Energy Interceptor.

In his keynote presentation, Mr. Matlock explained that threat is behind the current focus of missile defense intercept technologies. There are an estimated 5550-6250 missiles globally, not including those from the United States, China, Russia, or NATO. Fifty-two of sixty-five hit-to-kill intercept tests have been successful since 2001, with test complexity increasing after each success. Current Missile Defense Agency (MDA) objectives are focused on a Phase II with the goal of enhancing medium-range defense by 2015. Phase III calls for enhanced intermediate-range missile defense by 2018; Phase IV calls for early intercept of intermediate-range ballistic missiles (IRBMs) and intercontinental ballistic missiles (ICBMs) by 2020. To achieve these goals, MDA is encouraging collaboration in a broad range of supporting technologies, including remote sensing, directed energy systems, and propulsion technology (Figure 1).

Current MDA advanced technology programs in remote sensing include data fusion, space-based



Matlock speaks on advanced missile defense technologies.

(continued on page 9)

KEYNOTE HIGHLIGHTS (cont.)

sensor, infrared detector material, focal plane array, and image processor. Technology programs in directed energy research include high-energy lasers, laser diodes, high-altitude characterization, cryolasers, and lighter-weight optics. Other advanced research program areas include advanced algorithms, nanoelectronics, environmentally rugged electronics, microchip-inspection techniques, silicon carbide mirrors, advanced power supplies and technologies for increased energy levels and efficiencies, lightweight composites, advanced thermal shielding materials, housing structures, O-rings and bearings, and low-thrust plume signature modeling. The MDA is depending on investments in small businesses to lead the way in creating solutions to its current technology gaps.

Two primary drivers in the BMD interceptor mission are range and maneuverability. Range correlates to propulsion systems through long operating times, and maximizing the burnout velocity for maximizing the kinematic reach. Greater maneuverability necessitates flexible divert and attitude control systems with high divert ΔV for divert containment. To achieve these objectives, current and future propulsion investment areas for the MDA (Figure 2) include advanced axial propulsion and advanced divert propulsion. The primary objectives for advanced axial propulsion investments are to obtain lightweight materials, high-energy propellants, and long operating attitude control systems.



Richard Matlock with Ed Liu (left) and Frank Tse (right).

The primary objectives for investments in advanced divert propulsion include flexible diver/attitude control system (ACS) propulsion systems, shipboard compatible divert/ACS propulsion systems, low-mass components, and materials capable of withstanding high temperatures over long operating times.

The MDA's advanced upper stage solid propulsion technology goals are shipboard compatible ACS with reduced mass with long operation, high-performance class 1.3C propellant for improved specific impulse, and high-temperature resin composite cases for improved mass fraction. Investments in advanced liquid divert/ACS propulsion are in valves, thrusters, and propellant management devices, as well as high/low level ACS for precision control, reduced mass, and higher ΔV . Goals for investments in advanced solid divert/ACS propulsion are similar—they include high/low thrust level ACS subsystem for precision control with low mass, and low mass divert subsystems and component technology capable of multiple discrete divert events over a duration much longer than 100 seconds.



Figure 1. Supporting technology areas of potential collaboration, as shown in the presentation.

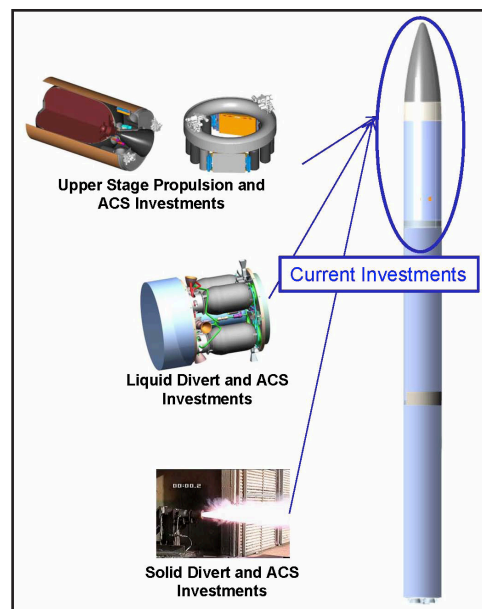


Figure 2. Slide from the address showing the current investment areas needed to achieve BMD interceptor mission objectives.

(continued on page 10)

JANNAF Gathers in San Antonio...continued from page 9

AWARDS

Following the keynote address, distinguished members of the propulsion community were recognized for their contributions to JANNAF.

Mr. Stuart Blashill announced that Mr. Stephen Mitchell of the Naval Surface Warfare Center received the JANNAF Executive Committee (EC) Lifetime Achievement Award in March 2012. The Executive Committee recognized Mitchell with these words, "This award is made in recognition of outstanding leadership and technical expertise in the fields of gun propellant formulation and combustion and for leadership and service in JANNAF. Your work has improved U.S. capabilities, enhanced collaborative efforts and raised the standards for safety and reliability."



Dennis McLaughlin presents Stephen Mitchell (left) with an EC Lifetime Achievement Award in March 2012.



Stuart Blashill presents Alice Atwood (right) with an EC Lifetime Achievement Award.

Mrs. Alice Atwood of the Naval Air Warfare Center Weapons Division was also awarded the JANNAF Executive Committee Lifetime Achievement Award. Mr. Blashill presented Atwood with the award and stated, "This award is made in recognition of outstanding leadership and technical expertise in the fields of propellant combustion, hazards, ordnance, and propulsion and for leadership and service in JANNAF. Your contributions in the areas of propellant and warhead ingredients and formulations, ordnance hazard testing methods and weapons hazard assessment protocols are recognized throughout the U.S. community and world."

Mr. James Taylor of NASA Marshall Space Flight Center received the JANNAF Executive Committee Special Service Award. Blashill presented the award by saying, "This Special Service Award is made in recognition of outstanding contributions to the JANNAF Interagency Propulsion Committee and leadership in the JANNAF Executive Committee. Your personal technical contributions and critical leadership abilities have significantly strengthened the U.S. capability in chemical propulsion."



Frank Tse with EC Special Service Award recipient Jim Taylor (right).

(continued on page 11)

JANNAF Gathers in San Antonio...continued from page 10

AWARDS (cont.)

The subcommittee awards for “Best Paper” at the 58th JPM in April 2011 were:

Structures and Mechanical Behavior (SMBS) Best Paper Award

Dr. Robert Hatch, NASA Glenn Research Center

“Constitutive Theory of High-Filled Solid Propellant with Non-Spherical Particles”

Propellant & Explosives Development and Characterization (PEDCS) Best Paper Award

Dr. Yu-Hui Chiu, Busek Co. Inc., Dr. Tommy Hawkins and Benjamin Prince, AFRL

“Theoretical Investigations of the Ionic Liquid Monopropellant AF-M315E”

Rocket Nozzle Technology (RNTS) Best Paper Award

Ms. Erin LaBarre, JHU/APL

“Validation for Computing B-Basis Allowables from a Single Batch of Carbon-Carbon”

Safety and Environmental Protection (SEPS) Best Paper Award

Mr. Edgardo Santiago-Maldonado, NASA Kennedy Space Center

“Chemochromic Indicators for the Detection of Hypergolic Fuels”

MEETING PROCEEDINGS

Proceedings for the meeting are published separately and available. Qualified customers may contact CPIAC at 410-992-7300 for more information or to order.

JANNAF Attendees Have A “Taste of San Antonio”





Kuo Receives JANNAF Lifetime Achievement Award



Dr. Kenneth K. Kuo, Distinguished Professor of Mechanical Engineering, Emeritus, and Director of the Pennsylvania State University High Pressure Combustion Laboratory, received a JANNAF Lifetime Achievement Award on December 6, 2011. On behalf of the JANNAF Executive Committee, Dr. Brad E. Forch presented Kuo with the award at the JANNAF Interagency Propulsion Committee meetings in Huntsville, AL.

The Executive Committee recognized Dr. Kuo with a plaque and these words, “This award is made in recognition of your 47 years of contributions to the entire JANNAF community. Your groundbreaking achievements in combustion science have been the vanguard in areas too numerous to list. Your life’s devotion has made a priceless impact upon where we as a nation stand today and will go tomorrow in combustion.”

Throughout his career, Kuo has published 480 papers—more than 100 of which have been published through JANNAF proceedings. He serves on the editorial advisory board of the *JANNAF Journal of Propulsion and Energetics*. To read the full press release about the award, please visit: http://www.mne.psu.edu/news/news_detail.cfm?nid=284.

In Memoriam

Prof. Edward Warren Price passed away on June 11, 2012. His long career in the fields of solid propellants combustion and solid propellants rockets began in 1941 at Caltech, where he worked on static firing of rocket motors. He served in the Navy from 1944-1946, working on solid propellants charge design and combustion at the Naval Ordnance Test Station (NOTS) in China Lake, CA.

After graduation in 1948 from the University of California, Los Angeles, with a bachelor’s degree in mathematics and physics, Ed returned to China Lake as a physicist for NOTS. NOTS became the Naval Weapons Center (NWC) and, in 1955, Ed became the head of NWC’s Research Department Gas Dynamics.

In 1974, after more than 30 years at NWC, Ed left to become a full professor at the Georgia Institute of Technology’s Daniel Guggenheim School of Aerospace Engineering. He was promoted to Regents’ Professor, an honorary professorship, in 1986, and retired from the university in 1991.

Ed was an active member of numerous committees and groups, including the JANNAF Interagency Propulsion Committee, the AIAA Solid Rockets Technical Committee, and the AIAA Publications Committee. He formed the JANNAF Combustion Working Group and served on a NASA panel following the 1986 Challenger explosion.

His contributions to science, engineering, and technical literature were recognized with the Navy Superior Civilian Service Award, the AIAA Goddard Award, the L.T.E. Thompson Award, the AIAA Research Award, the Pendray Aerospace Literature Award, a JANNAF Certificate of Recognition, and the NASA Public Service Award.

In Memoriam



Dr. William L. Hufferd passed away on April 29, 2012. He was a member of the JANNAF Structures and Mechanical Behavior Subcommittee and served as Director of the Chemical Propulsion Information Analysis Center from 1995-2005.

His long career in academia and the propulsion industry began in 1961, when he joined Lockheed Propulsion Company as an Analysis and Materials Engineer. In 1970 he became Associate Professor at the University of Utah's Civil Engineering Department. While at the university, he also held positions as Assistant-to-the-Dean of the College of Engineering, and Chairman of the College of Engineering Mechanics Division.

During the early 1980s, Bill performed engineering consultant services and, in 1984, joined United Technologies Chemical Systems Division. He held several positions at United—Senior Structural Research Engineer and Chief; Manager of the Engineering Analysis Branch; and Manager of the Propulsion Sciences, Research, and Engineering Department.

In 1995 Bill became the Director of the Johns Hopkins University Chemical Propulsion Information Agency. The following year, he led the University's successful proposal to the DoD for the continued operation of the CPIA—an award that extended Hopkins' continued operation of the CPIAC and its predecessor organizations to 58 consecutive years. Bill retired from CPIAC in 2005.

Bill served as Editor-in-Chief of the *JANNAF Journal of Propulsion and Energetics*, and authored more than 60 technical reports and papers on stress analysis, characterization and analysis of nonlinear viscoelastic materials, failure and fracture analysis, and material aging. He coauthored the *JANNAF Handbook for the Engineering Structural Analysis of Solid Propellants* and the *JANNAF Structural Integrity Handbook*.

Volume 5 of the JANNAF Journal of Propulsion and Energetics is Available!

Volume 5 of the *JANNAF Journal of Propulsion and Energetics* was released in April and distributed at the 2012 JPM. The issue features papers in the areas of hypersonic propulsion, exhaust plume, solid propulsion, and electric propulsion technologies. If you have not yet received Volume 5, be sure to pick up a copy at the next JANNAF meeting in December 2012. You may also order one by calling CPIAC at 410-992-7300.

The *JANNAF Journal* Call for Papers is ongoing. Submit your manuscript now for consideration in an upcoming issue. For questions about manuscript style or preparation, figures and graphics, submission procedures, and deadlines, please contact Journal Managing Editor Nicole Miklus at nmiklus@cpiac.jhu.edu. For matters related to technical topics, special focus areas, research, and data, please contact Editor-in-Chief Vigor Yang at JournalEIC@cpiac.jhu.edu.

J	ANNAF	\$75.00
JOURNAL OF PROPULSION AND ENERGETICS		
VOLUME 5, NUMBER 1 APRIL 2012		
Editor's Introduction		iii
Editor's Introduction	W. Yang, S.-J. Li, H.-K. Li, and W.-M. Shao	iii
HYPERSONIC PROPULSION TECHNOLOGY		
Effect of Chemical Composition of Rocket Propellant Pairs for Hypersonic Applications		1
	H. Peng and M. Han	1
EXHAUST PLUME TECHNOLOGY		
The Effect of Solid on the Radiation Intensity Emitted from Subsonic Rectangular Nozzle Plumes		11
	J. Li, H. Peng, S.-J. Li, and S.-J. Li	11
Mass Spectrometric Analysis of the Exhaustion Phase Emitted from an Externally Walled Nozzle Using a Jet		23
	J.-W. Zhang, S.-J. Li, S.-J. Li, and T.-W. Zhang	23
SOLID PROPULSION TECHNOLOGY		
In-Visco Approach to Rapid Velocity Assessment of Novel High-Nitrogen Energetics		41
	J.-J. Chen, W.-J. Zhang, and T.-W. Zhang	41
Composite Propellant Density Minimization Using a Particle Packing Algorithm with Random Volume Weighted Displacements		53
	J.-J. Chen, W.-J. Zhang, and T.-W. Zhang	53
Effect of the Oxidation State of Iron Catalyst on the Cure Rate of Epoxy-Adhesive-C/CFB Composites		67
	F. Agnew, F. Li, and M.-J. Li	67
ELECTRIC PROPULSION TECHNOLOGY		
Reaction and Lifetime Modeling of the HETS DBD		79
	J.-J. Chen, W.-J. Zhang, and T.-W. Zhang	79
Single Particle Simulations of Electron Transport in the Sheath of a HETS DBD/DC Thruster		91
	A. W. Smith, M.-J. Li, and T.-W. Zhang	91
MISCELLANEA		
Journal Information Board Editorial Staff, JOURNAL Editorial Standards for Publication of Propulsion and Energetics Research, Authors on the Documentation or Use of Technical Data Published in the JOURNAL, Journal Information Board, JOURNAL Manuscript Preparation and Submission Instructions, Advertising Information, Order Form for Previous Issues, and Associate Editors		101

60th JPM to Meet in Colorado Springs in April

9th MSS, 7th LPS, 6th SPS Joint Subcommittee Meeting

April 29-May 3, 2013, Colorado Springs, CO

Plans are underway for the Joint Army-Navy-NASA-Air Force (JANNAF) 60th JANNAF Propulsion Meeting/9th Modeling and Simulation Subcommittee (MSS)/7th Liquid Propulsion Subcommittee (LPS)/6th Spacecraft Propulsion Subcommittee (SPS) Joint Meeting to be held Monday through Friday, April 29-May 3, 2013, at the Cheyenne Mountain Conference Center (CMCC) in Colorado Springs, Colorado. Mr. Bruce R. Askins, NASA Marshall Space Flight Center, Huntsville, Alabama, is the Meeting Chair.

CALL FOR PAPERS: The call for papers for this meeting can be found at <https://www2.cpiac.jhu.edu/meetings/Apr2013/images/cfp.pdf>. Abstracts were due on **October 22, 2012**, but continue to be accepted.

In addition to the individual mission areas, papers are also solicited in distinctive special topic areas:

MSS

- Special Topic: Integrated Sensing Systems Needs/Approaches
- Special Topic: Models and Simulations of Shock-Shock interactions, Ablation, or Boundary Layer Transition at High Hypersonic Mach Numbers
- Special Topic: Space and Launch Vehicle Cost Estimation

LPS

- Special Topic: Advanced Upper Stage Engines
- Special Topic: Minimum Cost Design Launch Technology

SPS

- Special Topic: Spacecraft Modeling and Simulation

PROGRAM: The complete program will be available at <https://www2.cpiac.jhu.edu/meetings/Apr2013/pages/index.html>. Todd May, manager of the Space Launch System Program (SLS) Office, located at NASA's Marshall Space Flight Center, will be the keynote speaker. Slated for its first mission in 2017, the Space Launch System will be the nation's next heavy-lift vehicle for human and scientific exploration beyond Earth's orbit.

Previously, Mr. May was Marshall's Technical Associate Director. He managed more than 100 research projects in the Science and Mission Systems Office at Marshall, and oversaw a \$5 billion annual portfolio of space and Earth science missions as Deputy Associate Administrator in the Science Mission Directorate at NASA Headquarters.

His education includes MIT's Sloan School of Business and he has completed coursework at Auburn University for a doctorate in materials science. Mr. May's professional awards include NASA's Exceptional Achievement Medal and the Senior Executive Presidential Rank Award—one of the highest honors given for commitment to excellence in public service.

HOTEL RESERVATIONS: Sleeping rooms have been reserved with the Cheyenne Mountain Conference Center, Colorado Springs, Colorado. Negotiated concessions include free wireless internet access in guestrooms and public areas, all gratuities, fitness center access, and parking. These concessions are available only to attendees who are staying at CMCC and make their reservations before April 1, 2013. The room rate per night for all attendees will be at the prevailing



(continued on page 17)

60th JPM to Meet...continued from page 16

government per diem rate, currently \$83 plus tax (currently 9.4%). Reservations may be made through the hotel reservations number at 719-538-4000. Please refer to JANNAF when making your reservations to assure the negotiated rates.

QUESTIONS: Technical questions may be addressed to the following CPIAC technical representatives:

- JPM and SPS: Mr. David Owen (dowen@cpiac.jhu.edu/443-718-5008)
 - LPS: Mr. Pete Zeender (pzeender@cpiac.jhu.edu/443-718-5001)
 - MSS: Mr. Nick Keim (nkeim@cpiac.jhu.edu/443-718-5005)
- For all other meeting-related matters, please contact Patricia Szybist (pats@jhu.edu/410-992-7302).

Recent CPIAC Products and Publications

CPIAC Publication 730, *JANNAF 32nd Airbreathing Propulsion/32nd Exhaust Plume and Signatures Joint Subcommittee Meeting*, April 2011 (U)

CPIAC Bulletin, Volume 37, Number 6, November 2011

JSC CD-67, *8th Modeling and Simulation/6th Liquid Propulsion/5th Spacecraft Propulsion Joint Subcommittee Meeting*, December 2011

JANNAF Journal of Propulsion and Energetics, Volume 5, Number 1, April 2012

JANNAF-GL-2012-01-R0, *Test and Evaluation Guidelines for Liquid Rocket Engines*, May 2012

JPM CD-11, *59th JANNAF Propulsion Meeting*, May 2012

JSC CD-68, *41st Structures and Mechanical Behavior/37th Propellant and Explosives Development and Characterization/28th Rocket Nozzle Technology/26th Safety and Environmental Protection Joint Subcommittee Meeting*, May 2012

CPIAC Publication 394, *Hazards of Chemical Rockets and Propellants*, Partial Revision to Volume II, August 2012

CPIAC Subscriptions

CPIAC forwarded GFY 2013 subscription renewal packets to its customer base for continued products and services. We would like to take this opportunity to inform the community that a minimum subscription of \$1,775 entitles subscribers to unlimited free access for all employees of your organization to our Propulsion Information Retrieval System; any two online databases housed in our Chemical Propulsion Information Network (CPIN); and six hours (prepaid) of technical/bibliographic inquiry hours. For information concerning a CPIAC subscription and/or products and services, please contact Hwei-Ru Chen at 410-992-7300, ext. 212 or email hchen@cpiac.jhu.edu.

JANNAF Executive Committee

CHAIRMAN

Mr. Stuart Blashill

ARMY

Dr. Brad E. Forch

U.S. Army Research Laboratory/Aberdeen Proving Ground

Dr. Jay S. Lilley

U.S. Army AMRDEC/Redstone Arsenal

NAVY

Dr. Jeffrey J. Davis

Naval Air Warfare Center Weapons Division/China Lake

Mr. Robert E. Kaczmarek

Naval Surface Warfare Center/Indian Head

NASA

Dr. Thomas M. Brown

NASA Marshall Space Flight Center/Huntsville

Dr. Dhanireddy R. Reddy (D.R.)

NASA Glenn Research Center/Cleveland

AIR FORCE

Mr. Michael T. Huggins

Air Force Research Laboratory/EAFFB

Mr. Robert A. Mercier

Air Force Research Laboratory/WPAFB

EX OFFICIO

Mr. Andrew S. Culbertson

ODDR&E/OSD(AT&L)/Washington, DC

Mr. Garry M. Lyles

NASA Headquarters/Washington, DC



JANNAF Subcommittee Chairmen and CPIAC Representatives

Subcommittee/Chair	Deputy Chair	CPIAC Representative
<i>AIRBREATHING PROPULSION (APS)</i>		
Mr. Lawrence D. “Larry” Huebner NASA Marshall Space Flight Center	Dr. James W. Weber Air Force Research Laboratory/WPAFB	Mr. Ronald Bates
<i>COMBUSTION (CS)</i>		
Dr. Michael J. Nusca U.S. Army Research Laboratory	Dr. Christine M. Michienzi Naval Surface Warfare Center	Mr. Ronald Bates
<i>EXHAUST PLUME and SIGNATURES (EPSS)</i>		
Dr. Marty J. Venner Air Force Research Laboratory/EAFFB	Ms. Robin L. Miller Naval Air Warfare Center Weapons Div.	Mr. Nicholas Keim
<i>LIQUID PROPULSION (LPS)</i>		
Mr. James L. Cannon (Co-Chair) NASA Marshall Space Flight Center	Dr. Richard K. Cohn (Co-Chair) Air Force Research Laboratory/EAFFB	Mr. Peter Zeender
<i>MODELING and SIMULATION (MSS)</i>		
Mr. Eric J. Paulson Air Force Research Laboratory/EAFFB	Mr. Joseph C. Boyle Naval Air Warfare Center Weapons Div.	Mr. Nicholas Keim
<i>PROPELLANT and EXPLOSIVES DEVELOPMENT and CHARACTERIZATION (PEDCS)</i>		
Dr. James Carver U.S. Army AMRDEC	TBD	Mr. David Owen
<i>PROPULSION SYSTEMS HAZARDS (PSHS)</i>		
Mr. Daniel F. Schwartz Air Force Research Laboratory/EAFFB	Mr. Kevin P. Ford Naval Air Warfare Center Weapons Div.	Mr. Andrew Taylor
<i>ROCKET NOZZLE TECHNOLOGY (RNTS)</i>		
Mr. Rob Esslinger U.S. Army AMRDEC	Mr. Louie Clayton NASA Marshall Space Flight Center	Mr. David Owen
<i>SAFETY and ENVIRONMENTAL PROTECTION (SEPS)</i>		
Dr. Mark S. Johnson Army Public Health Command	Dr. David R. Mattie Air Force Research Laboratory/WPAFB	Mr. Andrew Taylor
<i>SPACECRAFT PROPULSION (SPS)</i>		
Dr. James M. Haas Air Force Research Laboratory/EAFFB	Mr. C. Les Johnson NASA Marshall Space Flight Center	Mr. David Owen
<i>STRUCTURES and MECHANICAL BEHAVIOR (SMBS)</i>		
Mr. Robert W. Pritchard Naval Air Warfare Center Weapons Div.	Dr. Timothy C. Miller Air Force Research Laboratory/EAFFB	Mr. David Owen

Calendar of JANNAF Meetings

45th Combustion Subcommittee (CS)/33rd Airbreathing Propulsion Subcommittee (APS)/33rd Exhaust Plume and Signatures Subcommittee (EPSS)/27th Propulsion Systems Hazards Subcommittee (PSHS) Joint Meeting

December 3–6, 2012

Hyatt Regency and Naval Postgraduate School, Monterey, CA

Hotel Reservations: Reservations may be made by calling Hyatt Regency reservations at 888-421-1442 or on the Web at <https://resweb.passkey.com/go/JANNAFIndustry>.

For additional information and registration, please visit: <https://www2.cpiac.jhu.edu/meetings/Dec2012/pages/index.html>.

60th JANNAF Propulsion Meeting/9th Modeling and Simulation Subcommittee (MSS)/7th Liquid Propulsion Subcommittee (LPS)/6th Spacecraft Propulsion Subcommittee (SPS) Joint Meeting

April 29–May 3, 2013

Cheyenne Mountain Conference Center, Colorado Springs, CO

Deadlines:

Papers due to CPIAC: April 1, 2013. Presentations due: April 15, 2013

For the JANNAF rate, hotel reservations must be made by April 1, 2013. Reservations may be made by calling the Cheyenne Mountain Conference Center at 719-538-4000. Please refer to JANNAF when making your reservations to ensure the negotiated rate.

For additional information and registration, please visit: <https://www2.cpiac.jhu.edu/meetings/Apr2013/pages/index.html>.

For additional information on the above JANNAF meetings, contact CPIAC Meeting Planner Pat Szybist at 410-992-7302, ext. 215, or by email to pat@jhu.edu.

Visit the JANNAF website for meeting updates: www.jannaf.org

Policy on Non-Government Attendees at JANNAF Meetings: Attendance is restricted to invited U.S. citizens. Non-government attendees must have their employment confirmed with an organization certified with the Defense Logistics Agency (DLA) to obtain export-controlled technical data AND be certified by a sponsoring government official from one of the participating JANNAF agencies. To attend the classified sessions, attendees must also possess a personal security clearance of at least Secret with a need-to-know in the areas of rocket, missile, space, aircraft, or gun propulsion. Information concerning registrations with DLIS can be obtained by contacting DLIS at (800) 352-3572 (www.dlis.dla.mil/jcp/). Questions concerning attendance eligibility should be directed to the CPIAC Facility Security Officer, Mary Gannaway, at (410) 992-7304, ext. 211.