NASA Glenn Research Center Expands Horizons and Opens Frontiers to Air and Space

Since 1941, the men and women of the NASA John H. Glenn Research Center at Lewis Field have been pioneers and innovators whose work has expanded horizons and opened frontiers for explorers in air and space. Today, the Center defines and develops propulsion, space electrical power, and communications technologies for NASA’s aeronautics and space missions.

The National Advisory Committee for Aeronautics (NACA) established the Aircraft Engine Research Laboratory in 1941. The Laboratory’s initial mission was to advance American engine development to keep stride with the Europeans. Some of the Laboratory’s early tasks helped in the World War II effort by developing a cooling system for the B-29 Superfortress and by studying aircraft icing to help planes fly “the hump” over the Himalayas into China.

In the late 1940’s, the Cleveland Laboratory was first renamed the Flight Propulsion Research Laboratory and then, following the death of NACA aeronautics pioneer George W. Lewis in 1948, the Lewis Flight Propulsion Laboratory. The change marked the transition from a laboratory limited to aircraft engines to one free to explore all areas of propulsion research. Rocket engine and fuels research began in 1945 with work on liquid hydrogen as a high-powered rocket fuel. That pioneering work lead, after another name change, to one of its most significant achievements thus far—the development of the Centaur rocket, the most powerful upper stage in the U.S. space program.

When the U.S. Space Act dissolved NACA in 1958 and created in its place the National Aeronautics and Space Administration, the Lewis laboratory, became part of the foundation of the new agency and was renamed the Lewis Research Center. In 1963, the Lewis Center successfully launched its first Atlas/Centaur rocket. Lewis experts managed the launch of the Atlas/Centaur and Titan/Centaur booster vehicles and the Agena upper stage rockets for the next 35 years. These launches sent to the sky weather and communications satellites and planetary exploration spacecraft, such as Surveyor, Pioneer, Viking, and Voyager, which studied the Moon, Mars, and the outer planets. All together, Lewis managed more than 119 unmanned launches.

In March 1999, the Center was formally renamed the John H. Glenn Research Center at Lewis Field. The new name honors John H. Glenn, Jr., the first American to orbit the Earth and longtime U.S. Senator from Ohio, who made history again in October 1998 by returning to space at the age of 77. The designation of the historic site upon which the Center is built as Lewis Field celebrates the legacy of George W. Lewis.

The Glenn Research Center main site, Lewis Field, is a 350-acre campus, adjacent to Cleveland Hopkins International Airport. Key aeronautics facilities include five wind tunnels, the Aero-Acoustic Propulsion Laboratory, the Engine Components Research Laboratory, the Propulsion Systems Laboratory, and the Engine Research Building. The Flight Research Building (Hangar) supports aircraft research operations for Glenn’s aeronautics, microgravity, solar cell, and icing research. Several Lewis Field facilities are used to simulate the space environment. These include the Electric Propulsion Laboratory, the 2.2-Second Drop Tower, and the Zero Gravity Research Facility. The Space Experiments Laboratory, the Telescience Support Center, and ground stations for satellites support Spaceflight operations. A Fabrication Shop, the Research Analysis Center, and a variety of other operational facilities support all of the facilities.

NASA Glenn also includes the 6400-acre Plum Brook Station near Sandusky, Ohio, 50 miles west of Cleveland. The primary facilities there are the Hypersonic...continued on page 4
CPIA’s Technical/Bibliographic Inquiry Service

CPIA offers a variety of services to its subscribers, including responses to technical/bibliographic inquiries. Answers are usually provided within three working days, and take the form of telephoned, telefaxed, 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 program tapes and instructions, and/or theoretical performance calculations. The CPIA staff responds to nearly 800 inquiries per year from over 180 customer organizations. CPIA invites inquiries via telephone, fax, email, or letter. For further information, please contact Tom Moore at (410) 992-7306, or email: tmooore@jhu.edu. Representative recent inquiries include:

Technical Inquiries

- Hazard classification of ammonium perchlorate as a function of particle size (TI2000052302).
- Aerodynamic inlets and rocket-based combined cycles (RBCC) (TI2000032104).
- Solubility of helium in nitrogen tetroxide and monomethylhydrazine (TI2000032401).
- Heat of formation for methyl centralite and cobalt carbonate (TI2000032402).
- Chemical formula and heat of formation for xylidine and triethylamine (TI2000032810).
- U.S. ballistic missile and large launch vehicle booster propellant formulations (TI2000032902).

Bibliographic Inquiries

- Firebolt hybrid propulsion system (BI2000052601).
- Propulsion system and launch vehicle health monitoring (BI2000042405).
- SRM plume quench modeling and techniques (BI2000042602).

CPIA Bulletin/Vol. 26, No. 5, September 2000
The following are various meetings and events. We welcome all such announcements, so that the propulsion community can be better served with timely information. See back page for the JANNAF Calendar.

<table>
<thead>
<tr>
<th>2000</th>
<th>Topic</th>
<th>Sponsor</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/13</td>
<td>U.S. Navy Theater Ballistic Missile Defense Conference</td>
<td>NDIA</td>
<td>Laurel, MD</td>
</tr>
<tr>
<td>9/18-20</td>
<td>Aerospace Materials, Processes, and Environmental Technology Conference</td>
<td>MSFC</td>
<td>Huntsville, AL</td>
</tr>
<tr>
<td>10/2-6</td>
<td>51st International Astronautical Congress (IAF)</td>
<td>*AIAA</td>
<td>Rio de Janeiro, Brazil</td>
</tr>
<tr>
<td>10/10-13</td>
<td>3rd International Conference on Spacecraft Propulsion</td>
<td>CNES/ESA</td>
<td>Cannes, France</td>
</tr>
<tr>
<td>10/20-11/1</td>
<td>Space Business Conference and Exhibition</td>
<td>AIAA</td>
<td>San Jose, CA</td>
</tr>
<tr>
<td>10/26-27</td>
<td>12th Annual Penn State Propulsion Engineering Research Center Symposium on Propulsion</td>
<td>PERC/ GRC</td>
<td>Cleveland, OH</td>
</tr>
<tr>
<td>11/6-9</td>
<td>Information Solutions for the 21st Century</td>
<td>DTIC</td>
<td>Rockville, MD</td>
</tr>
<tr>
<td>11/7-9</td>
<td>AIAA 2000 Missile Sciences Conference</td>
<td>AIAA</td>
<td>Monterey, CA</td>
</tr>
<tr>
<td>11/21-24</td>
<td>2nd European Conference on Launcher Technology: Solid Space Propulsion</td>
<td>CNES</td>
<td>Rome, Italy</td>
</tr>
<tr>
<td>11/27-30</td>
<td>Insensitive Munitions and Energetic Materials Symposium</td>
<td>*NDIA</td>
<td>San Antonio, TX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2001</th>
<th>Topic</th>
<th>Sponsor</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8-11</td>
<td>39th AIAA Aerospace Sciences Meeting and Exhibition</td>
<td>AIAA</td>
<td>Reno, NV</td>
</tr>
<tr>
<td>7/8-11</td>
<td>37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit</td>
<td>AIAA</td>
<td>Salt Lake City, UT</td>
</tr>
<tr>
<td>11/6-8</td>
<td>18th Symposium on Explosives and Pyrotechnics</td>
<td>FAPI</td>
<td>Philadelphia, PA</td>
</tr>
</tbody>
</table>

AIAA = American Institute of Aeronautics and Astronautics (703) 264-7500, (800) 639-2422, or www.aiaa.org
*AIAA = American Institute of Aeronautics and Astronautics, C. Gourdet 331-4567-4260
CNES = Centre National D’Etudes Spatiales, Christine Correcher +33 5 61 28 23 88, or christine.correcher@cnes.fr
DTIC = Defense Technical Information Center, Ms. Julia Foscue (703) 767-8236, foscue@dtic.mil, or http://www.dtic.mil/dtic/annualconf
FAPI = Franklin Applied Physics, Inc., James G. Stuart, Ph.D. (610) 666-6645
MSFC = Marshall Space Flight Center, Jodi Weiner (256) 533-5923, or jweiner@aol.com
NDIA = National Defense Industrial Association, Ms. Kanzada Douglass (703) 247-2586, kdm@ndia.org, or www.ndia.org
*NDIA = National Defense Industrial Association, fbajowski@ndia.org
PERC/GRC = Propulsion Engineering Research Center, NASA Glenn Research Center, Ohio Aerospace Institute, John Raiser (814) 863-6274, or jcrper@engr.psu.edu

For contact information, please see The Bulletin Board.
The Propulsion Systems Laboratory (PSL) is NASA’s only ground-based test facility that can provide true flight simulation for experimental research on air-breathing propulsion systems. The complex houses two direct-connect engine test cells, each 24 ft in diameter and 38 ft long. Altitudes to 70,000 ft and Mach numbers to 3 in one cell and 6 in another can be continuously simulated. Engine airflow is available to 480 lb/s at an inlet pressure of 55 psia or to 380 lb/s at 165 psia. Inlet temperature control is also available.

Engine thrust can be measured in three dimensions. Steady state and transient data systems are interfaced with roughly 1800 individual test parameters such as pressure, temperature, and flow. Real-time display and post-test data reduction are available for all measured and calculated parameters.

The Space Power Facility (SPF) houses the world’s largest space environment test chamber, measuring 100 ft in diameter by over 120 ft in height. The facility was designed and constructed to safely test both nuclear and non-nuclear space hardware in simulated low-earth environments.

This facility can sustain a high vacuum ($10^{-6}$ torr); simulate solar radiation via a 4-MW quartz heat lamp array, solar spectrum by a 400-kW arc lamp, and LEO plasma via argon plasma generation. It also has a large experiment-assembly area (150 ft long by 75 ft wide by 76 ft high); a correspondingly large clean assembly area where radioactive hardware can be safely disassembled; a 16,000 ft² office building; and a large instrumentation area equipped with computers and data acquisition equipment. A cryogenic cold wall is also available.

The Spacecraft Propulsion Research Facility is the largest space environment test chamber in the United States for full-scale rocket engine testing at up to 200,000-lb thrust. Designed to test liquid hydrogen/oxygen rocket engines, it houses a 38 ft diameter by 62 ft high stainless steel test chamber. The facility can provide sustained high vacuum ($10^{-6}$ torr); solar thermal simulation via a quartz lamp array; a 250-ton floor load capacity; a liquid-hydrogen ($\text{LH}_2$) supply to the test articles via vacuum-jacketed piping and installed chamber penetrations; a 200,000-gal $\text{LH}_2$ storage tank nearby; additional $\text{LH}_2$ storage in railcar-mounted tanks; a 19,000-gal propellant safety dump tank and a 6000-gal liquid oxygen ($\text{LO}_2$) oxidizer safety dump tank located below the test chamber, to receive and contain accidental $\text{LH}_2$ or $\text{LO}_2$ spills; and a water spray chamber/steam ejector system to cool/remove rocket exhaust.

The Cryogenic Propellant Tank Facility is a 25 ft in diameter space environment test chamber with a 20 ft in diameter door. The facility’s design and construction allow large-scale liquid hydrogen ($\text{LH}_2$) experiments to be safely conducted. This facility has a removable $\text{LH}_2$/LN$_2$ cryogenic cold wall capable of simulating deep space temperatures down to -423 °F; electrical control systems with explosion-proof hardware; a hydraulic shaker system; and an $\text{LH}_2$ dump line and burn pit to handle accidental $\text{LH}_2$ spills inside the chamber. The facility can provide vacuum to $10^{-6}$ torr without the cold wall, and $10^{-4}$ torr with the cold wall in operation.

The Cryogenic Propellant Tank Facility continues to play an essential role in the development of advanced insulation systems and on-orbit fluid transfer techniques for flight-weight cryogenic fuel tanks and insulation systems. Experiments were recently conducted in the production and utilization of slush hydrogen (a higher density mixture of liquid and solid hydrogen). The facility is equipped with an 800-gal slush hydrogen batch production plant. Results of such experiments have application in developing high-speed aerospace-craft of the future.

The Hypersonic Tunnel Facility (HTF) is a blowdown freejet wind tunnel capable of simulating Mach 5 through Mach 7 flow velocities. The test chamber, which is fed through a 42-in. nozzle, allows articles up to 2 ft in diameter by 10 ft in length to be tested. Temperature, altitude, and air composition can be generated for hypersonic engine or airframe tests in simulated flight environments. Heating clean nitrogen gas with a 3.5-MW electric induction heater produces the high stagnation temperatures in this facility. The hot nitrogen gas is then mixed with clean oxygen to yield the air composition for the test.

Features of the facility include a 9 ft in diameter by 40 ft tall electric induction heater capable of storing 77 million Btu at 5000 °R; storage for 700,000 ft³ of gaseous nitrogen in addition to 500,000 ft³ of gaseous oxygen; and onsite storage for liquid hydrogen ($\text{LH}_2$) in an 810 ft³ Dewar supporting $\text{LH}_2$ flow rates to 45 lb/s. Under normal operating conditions the facility can accommodate a 5-min test run every 24 hours.

NASA Glenn is contributing its expertise to investigations of several generations of future space launch vehicles aimed at achieving the affordable access to space goals of reducing the cost of getting to low Earth orbit for $10,000 to $1,000 per pound of payload. The X-33—a pilotless, suborbital plane—will test the viability of a

---

GTX concept of a rocket-based combined cycle aerospace plane.
fully reusable, single-stage launch vehicle. If its commercial successor is built, it will depend on several Glenn developments: new propellant technologies, engine health monitoring systems, and an automated ground support system.

Increasingly, air and space vehicles are synthesizing not only to push the boundaries of flight, but also to blend them. Future space vehicles will combine the advantages of aircraft and rockets. The GTX—a low-cost combined rocket and airbreathing engine vehicle—is Glenn’s low-risk approach for a vehicle that operates like an airplane as it climbs through the atmosphere, then switches to rocket mode to achieve orbit. A GTX-like vehicle could reduce payload launch costs to hundreds of dollars per pound and help turn space into an even more viable workplace and a truly accessible habitat.

NASA Glenn is developing new methods for spacecraft propulsion and positioning to improve the capabilities of deep space probes. Ion engines, once considered the stuff of science fiction, are now being used by industry for satellite station keeping, while NASA has begun using them as the primary propulsion source for missions such as Deep Space 1. The Hall thruster—tested at Lewis in the 1960’s and developed further by Russia’s space agency—is America’s newest form of satellite propulsion. Weighing 40 percent less than chemical thrusters, Hall thrusters may be used to raise satellites to higher orbits and to propel interplanetary spacecraft. Pulsed plasma thrusters are being used for precise positioning of the very small satellites that are forming networks around Earth.

The Future of Glenn Research Center

The research and advancements cited in this article are only a portion of the activities underway at NASA Glenn. The work done in Glenn’s unique, world-class facilities continues to push technology to its limits and achieves new levels of exploration and invention. Glenn Research Center’s collaborative relationships with other NASA Centers make it a vital part of an extraordinary NASA team—a team that is leading the way in expanding the frontiers of air and space.

For further information, please contact Dr. Louis Povinelli, chief scientist for turbomachinery and propulsion systems, via email at Louis.A.Povinelli@grc.nasa.gov.
The Twenty Ninth Department of Defense Explosives Safety Seminar, presented by the United States Department of Defense Explosives Safety Board (DDESB) was held 18-20 July 2000 in New Orleans, Louisiana. There were approximately 710 attendees from 18 different countries and the U.S.

One hundred and seventy-eight papers were presented in 34 technical sessions including one poster session. In addition, 15 exhibits were on display for all three days.

Areas of interest included: Accidents; Barriers & Blankets; Barricades; Barriers & Dividing Walls; Chemical Warfare Materials; Cook-off (Slow Heating) of Explosives; Debris & Fragments; Debris Models; Explosive Testing, Modeling and Simulation; Explosive Materials Sensitivity/Hazards; Explosives Materials & Munitions Sensitivity/Hazards; Ground Shock; Hazard Classification and IM Testing; Glass Hazards/Effects; Hazard Classification; Hazard Classification and IM Testing; High Performance Magazine; Insensitive Munitions; Military Operations-Explosives Safety; Ordnance & Explosive (OE) Site Operations Aides; Ranges; Range Residue & Disposition; Risk-Based Safety; Safety Policy; Structures-Loads & Response; 40 TONNE; Underground Storage; UXO Detection; UXO Technology & Remediation; and Water Mitigation of Explosion Effects.

The proceedings of the seminar will be available on CD-ROM in approximately four months and will automatically be sent to all attendees. Additional copies will be available from CPIA. The cost for the proceedings for non-attendees is $150.00 and can be ordered by contacting Dottie Becker at (410) 992-7302, ext. 204, or email: dlbecker@jhu.edu.

The next DoD Explosives Safety Seminar will be held in the Summer of 2002. The exact date and site have not yet been determined.
Dr. Ingo W. May retired as the Director of the Weapons and Materials Research Directorate of the U.S. Army Research Laboratory at the end of June 2000. Previously, Dr. May served as Chief of the Propulsion and Flight Division in the Weapons Technology Directorate and Chief of the Interior Ballistics Division of the Ballistics Research Laboratory.

Dr. May has authored or co-authored over 70 reports and publications and has presented over 100 technical papers on ballistics to national and international scientific organizations.

During his career, Dr. May has received numerous awards: He was elected as Fellow of the Ballistic Research Laboratory in 1975. He received the Army Meritorious Civilian Service Award in 1979, the Department of the Army Exceptional Civilian Award in 1984, and the Senior Executive Service Presidential Rank Award for Meritorious Executives in 1993.

On June 28 at the Naval Air Warfare Center Weapons Division (NAWCWD) in China Lake, Thiokol Propulsion signed an exclusive licensing agreement for Thiokol’s production of CL-20. A new cooperative research and development agreement (CRADA) links Thiokol and the NAWCWD in further studies of CL-20.

The energetic molecule CL-20—hexanitrohexaasaisowurtzitane in chemists’ terms—was invented by Dr. Arnold Nielsen, a former China Lake chemist, in 1987. CL-20 has been described as the world’s most powerful nonnuclear explosive. Moreover, CL-20 formulations have the potential for remarkable stability and resistance to external stimuli, which translates into increased safety.

In addition to ordnance applications, CL-20 formulations are well suited for missile propellants. CL-20 burns cleanly, making it more environmentally friendly as well as reducing a missile’s plume signature. Furthermore, CL-20 can also enhance products for commercial applications.

The Navy has granted Thiokol an exclusive license to manufacture and sell CL-20 through 2008. Under the CRADA, Thiokol and NAWCWD will work to improve the synthesis procedures for CL-20 with Dr. Bob Wardle (Thiokol) and Dr. Bob Chapman (NAWCWD) as principal investigators. Interest in fully developing the potential of this energetic material is intense and widespread. Thus far, Thiokol has produced more than 10,000 pounds of CL-20 for DoD research-and-development programs and for U.S. allies.

SPIRITS Computer Code Updates

SPIRITS-AC2r0, which includes SPIRITS-AC1r1 and SPIRITS 4.2. This new version will be automatically sent to all users of the SPIRITS computer code who are current with their two-year renewal fees. Other users or anyone who is interested in obtaining this computer code should contact Dottie Becker at (410) 992-7302, ext. 204 or email to dlbecker@jhu.edu.

CPIA has also received the following five SPIRITS Target Modules: F-15E; C-130H; B-52H; C-17A; and ALCM. (These modules are in addition to the F16C and B1B modules that are also available from CPIA.) Each module is available at a cost of $234.00 to current users of the SPIRITS computer code. To place your order, please contact Dottie Becker, (additional administration fee of $30.00 for all invoiced charges.)

Visit the New CPIA Web Site!

Our new web address is www.cpiajhu.edu

New Features and Benefits:
• New look
• Easier navigation
• New search engine
• Printable order forms for PIRS and CIRS (additional product forms under development)

Our new location will allow us to bring you new and improved features into the future. (You will be automatically transferred to our new site when you go to the old URL.)
### JANNAF MEETING CALENDAR

<table>
<thead>
<tr>
<th>Year</th>
<th>Meeting</th>
<th>Type</th>
<th>Location</th>
<th>Abstract Deadline</th>
<th>Paper Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Attendance at JANNAF Conferences and Workshops is by invitation only.

MEETING CALENDAR SUBJECT TO CHANGE. FOR LATEST DETAILS, CONTACT CPIA AT (410) 992-7304.