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GSFC NEWS

tech transfer

Shuvo Mustafi makes adjustments to a model of a new Thermodynamic Cryogen Subcooling System that is being designed to enable longer space flights.

Photo courtesy of Chris Gunn

in this issue:

from the chief

This issue of *Goddard Tech Transfer News* represents a bit of a departure from some of our other recent issues. Instead of focusing on a specific mission, in this issue we turn our attention to the key technologies resulting from Goddard's support of exploration systems technology needs. Over the years Goddard has gained a great deal of experience supporting science missions such as the Hubble Space Telescope, Lunar Reconnaissance Orbiter, and the Solar Dynamics Observatory, working on projects that consistently place a premium on new technology development that emphasizes speed, small size, and light weight. These technologies, and our experience, can now be leveraged to other applications, both within NASA and beyond.

Nona Cheeks

As the Chief of the Goddard Innovative Partnerships Program Office, an essential responsibility of the role I lead is to disseminate information about Goddard's technical achievements with the purpose of building awareness of capabilities and creating opportunities for new partnerships based on Goddard's technologies and expertise.

As you're about to see in the following pages, Goddard technologies that were developed in support of NASA's interest in exploration systems offer a wide range of commercial possibilities. Some of these opportunities are fairly self evident. For example, our communications related technologies can be utilized in many different applications where high-speed, high-bandwidth networking is critical. The commercial potential for other technologies may seem less obvious at first glance, but ultimately may be just as valuable. For instance, one cryogenic technology, originally developed for subcooling liquid rocket fuel, may be adapted to serve as an advanced storage technology for hydrogen – which is being widely hailed as an important component of our future energy strategy in markets as diverse as automobiles, aircraft, and fuel cells.

These and several other key Goddard technologies are highlighted in this issue. Our goal is to illustrate how our technologies can continue to solve critical problems and provide high value across a broad spectrum of applications – long after the missions for which they were originally designed have completed. Please read on to learn more, and enjoy!

Nona Cheeks
Chief, Innovative Partnerships Program Office (Code 504)
NASA's Goddard Space Flight Center ■

An image of the Deepwater Horizon oil spill in the Gulf of Mexico captured on May 17, 2010 by the Moderate-Resolution Imaging Spectrometer (MODIS) on NASA's Terra Satellite. MODIS is just one example of how technologies developed at Goddard can be used to analyze, understand, and coordinate response to critical environmental issues.

This month we interview three senior members of the Exploration Systems Projects team: Mike Weiss (Project Manager), Neal Barthelme (Deputy Project Manager), and Ron Leung (Senior Mission Systems Engineer & Independent Technical Authority). Mike, Neal, and Ron spoke to us about Exploration Systems Projects' technologies and the critical value they can provide both within NASA and beyond.

Could you tell us a little about the mission of the Exploration Systems Projects team?

Mike: We're the front door for Goddard's contributions to NASA's Exploration activities, providing technologies and engineering services that enable NASA to expand space exploration capabilities beyond Low Earth Orbit (LEO). NASA needs advances in technologies that enable our exploration goals. We need to move beyond current space system architectures to systems that include distributed avionics, non-satellite-based GPS navigation capabilities, cryogenic fuel management systems, advanced materials, higher data rate communication systems, and autonomous rendezvous and docking sensors and software. Goddard has the experience and capability to contribute to NASA's most pressing technology development needs.

Neal: What we bring to the table are a certain set of skills. The areas we are most involved with include avionics, communication and navigation systems, science integration, and secondary payload accommodations on NASA vehicles. Secondary payload accommodations is actually a technology enabler. The entire science and technology community is starved for access to space opportunities. We intend to use our extensive Shuttle payload experience to help NASA utilize every ounce of lift margin capacity as NASA embarks on heavy lift vehicle development.

Ron: Our experience in supporting Earth and space science missions has provided us with a lot of experience developing enabling technologies. Our goal now is to leverage that experience, and the technologies we've developed, for other applications. These can include missions within NASA, but they can also include commercial applications. One example is composite materials. We've done a lot of work in this area because it's often important for satellites to be as light and strong as possible. We're now finding that these composite materials are very useful in other applications, anything where weight can be an issue. There's a lot of demand for this type of technology. We call this "cross-cutting."

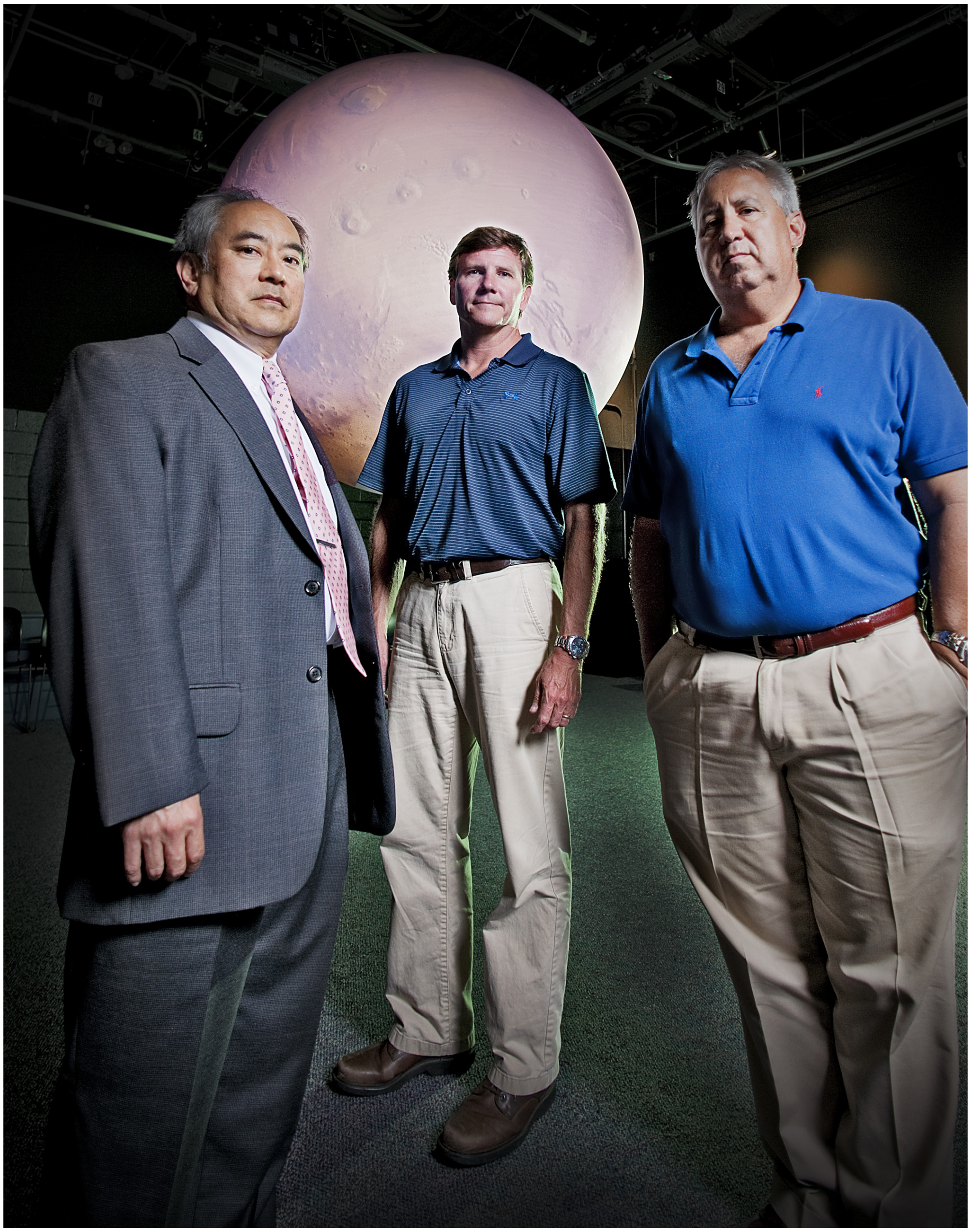

Photo courtesy of Chris Gunn

Left to Right: Ron Leung, Neal Barthelme, Mike Weiss

Could you expound upon the idea of "cross cutting"?

Mike: Cross cutting is a core theme to what we're doing. It means developing a technology for one application, and then finding ways to use it in other applications. This allows us to do things quicker and faster. In this way, we become technology enablers.

Neal: Think of it in terms of multiuse and multifunction. If a technology we've developed for a previous mission solves a new problem, we don't have to reinvent it. These technologies developed for science missions can then "cut across" and support other missions and applications. Some of these other applications will involve other NASA centers, while others have significant commercial potential. For instance, we're very active in optics and optical communications, which is great for any high-bandwidth data transmission requirements. Combined with our work with standards, this can in theory extend the internet to practically anywhere – the moon, Mars, and beyond.

Mike Weiss

Code: **455**

Years with NASA: **33**

Field of research:
Spacecraft Design, Program and Project Management

Birthplace: **Austin, TX**

Education:
MS Aerospace Engineering University of Maryland at College Park

Ron: This type of communication architecture is the sort of thing everybody has to have. For example, right now, we really can't pipe down a lot of high-definition video from space. Optical will let us do that. These new architectures will be multi-dimensional, opening up possibilities for transmitting huge amounts of data very quickly.

What are some of your other core technologies?

Neal: In addition to optics and lightweight materials, which we've already mentioned, we're also involved in decisional systems, software which readily locates, retrieves, and analyzes a wide variety of distributed lunar data archives, such as Integrated Lunar Information Architecture for Decision Support (ILIADS) (GSC 15339-1, GSC 16209-1, GSC 16210-1). But this type of software lends itself to plenty of other applications, such as other future missions that may be planned to near Earth objects (NEOs), Mars and its moons, and other deep space destinations. This type of software application can be used on a desktop in a control center or embedded into lunar rovers to support real-time lunar surface mission operations.

What technologies have already found commercial applications?

Ron: One of our success stories is LIDAR [light detection and ranging]. This is another example of an optical technology, an area at which Goddard excels. One example of a LIDAR technology is the Lidar System for Airborne Measurement of Clouds and Aerosols (GSC-14985-1). The technologies we've developed have been used for applications such as vegetation mapping and altimetry. We've got a team [Code 613.1] dedicated to LIDAR, and they've been involved in things

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like weather prediction and climatology, including global warming.
Mike: We mentioned lightweight materials earlier. One material we flew into space on the final Hubble Servicing Mission (STS 125) was a carbon/carbon composite support structure. While the material itself already existed, the technologies associated with using it in a space application were developed here at Goddard and are now flight-proven. If NASA is going to deliver more mass to destinations beyond LEO, we will need to make huge advances in materials and propulsion. Detectors are another area. The DDL [Detector Development Lab] is a unique facility that allows Goddard to test and characterize state-of-the-art detectors. We've made a lot of these technologies available to the community.

What's next for Exploration Systems Projects?

Mike: In some respects, this is a question that we're in the process of refining. Traditionally, Goddard has been a primary science center for NASA, along with the Jet Propulsion Laboratory (JPL). Our missions largely involved Earth and Space science. As NASA expands its exploration capabilities beyond LEO, new technologies that enable both the exploration architectures and the science data return capabilities will be needed.

We support the idea of "one NASA" in which we're no longer just a collection of centers, each with one specific and separate mission, but instead we're part of this larger entity. Within that environment any technology should be considered if it can solve a NASA problem, irrespective of where that technology originated. And once you start doing that – thinking about how something you've invented for one purpose can be applied to another – you start seeing all sorts of other possibilities for your technologies, including commercial. There are so many opportunities here; we want to take full advantage of as many of them as we can. ■

Neal Barthelme

Code: **455**

Years with NASA: **27 years**

Field of research:
Project Management

Birthplace: **Timonium, MD**

Education:
BS Computer Science, Loyola College

Ron Leung

Code: **592**

Years with NASA: **27 Years**

Field of research:
Digital Systems Control & Communications

Birthplace: **Washington, DC**

Education:
BS Electrical Engineering & MEA, George Washington University

Advanced Cryogenic Fluid Management

Liquid hydrogen and liquid oxygen have been used as fuels to launch vehicles into space for over 50 years. These cryogenic propellants allow a greater percentage of the vehicle's initial mass to be devoted to payload.

Unfortunately, the use of cryogenic fuels is currently limited to launch vehicles where hold times are minimal, due to the fact that these fluids boil off easily. Liquid hydrogen, for example, boils at 20 degrees Kelvin at atmospheric pressure (only 20 degrees above absolute zero). As the liquid boils, the resulting hydrogen gas needs to be vented, reducing the amount of fuel available for propulsion.

Thermodynamic Cryogen Subcooler (TCS)

To address this need, the Goddard Cryogenics and Fluids Branch (Code 552) is developing cryogenic propellant storage and transfer (CPST) technologies for long-term storage of cryogenic propellants. For example, GSFC is developing a thermodynamic cryogen subcooler (TCS) (GSC-15603-1) that will provide a compact method for subcooling and maintaining cryogenic propellants on the launch pad for upper-stage or propellant-depot supply applications.

According to Shuvo Mustafi, this system will "subcool" the liquid hydrogen to below its 20 degrees Kelvin boiling point at one atmosphere pressure, by using a small fraction of the liquid hydrogen supplied to the propellant tank for launch to chill the bulk hydrogen in the propellant tank that will be launched. This will reduce cryogenic propellant boil-off, and deliver months of vent-free cryogenic propellant.

The TCS will be compact, incur low transfer losses, and have low peak power and consumables usage. Subcooling and thermodynamic maintenance on the launch pad will ease launch logistics and increase operational flexibility without adding any significant launched mass. After launch, the heating of the subcooled cryogenic propellant allows it to absorb the large quantities of energy that leak into the tank. During this period of heating of the subcooled cryogen there will be no loss of the propellant due to venting. In fact, the TCS would triple the in-space vent-free hydrogen storage time.

Back on Earth, cryogenic storage of hydrogen is likely to be an increasingly important commercial need in the upcoming years. Hydrogen is being widely hailed as the "fuel of the future," offering clean, renewable energy for applications such as automobiles and fuel cells. The handling and storage of hydrogen play an important part of its adoption, as technologies are developed to ensure that hydrogen can be transported and stored safely and made readily available to consumers.

For example, commercialization of hydrogen fuel cell vehicles is expected to take place from 2015 to 2020 with an estimated 2 million hydrogen vehicles in operation by 2020 and up to 25 million by 2030. A study by the Fuel Cell Partnership assumes a hydrogen fuel station capacity of 400 vehicles; this suggests a need for 5,000 such facilities in 2020, rising to 62,500 by 2030. All these facilities (not to mention many other central generation, storage, and shipping facilities) will comprise a significant market for advanced hydrogen storage technologies such as cryogenics. This may be an excellent commercialization opportunity for the TCS, offering a highly efficient, state of the art method for providing storage for society's growing need for hydrogen fuel.

And according to Shuvo, another future application for this technology might be aircraft that would use hydrogen as fuel.

Shuvo Mustafi

Code: **552**

Years with NASA: 13

Field of research: **Cryogenics and Fluids**

Birthplace: **Hoboken, NJ**

Education: **BS, Purdue University; MS, Johns Hopkins University; PhD (Ongoing), University of Maryland College Park**

A simplified diagram of the TCS

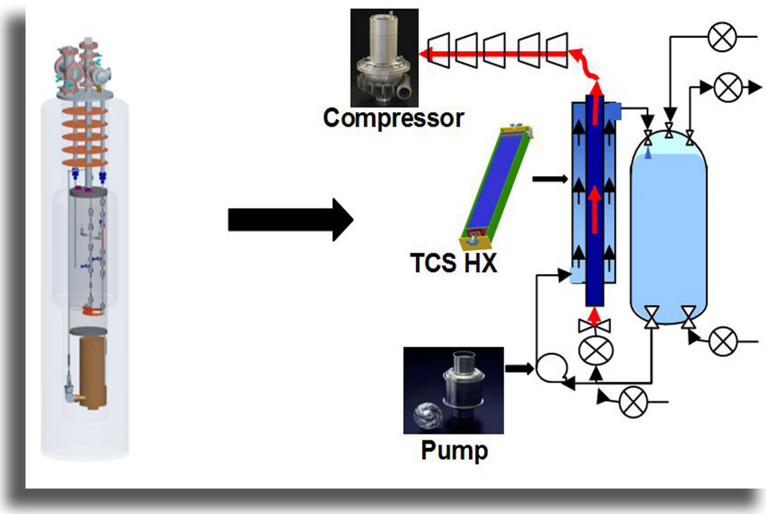


Image courtesy of Shuvo Mustafi

In this situation, it would be essential to carry the hydrogen as at least a liquid and preferably in a densified/subcooled form.

Other Cryogenic Technologies

Other areas of focus for GSFC CFM technologies include technologies related to the co-storage of cryogenic propellants, distributed cooling, passive storage innovations involving multi-layer insulation, and thermally isolating structures, active storage concepts involving cryocoolers and the development of cryogenic fluid transfer couplings. Potential applications include:

•**Infrared Sensors.** Infrared rays, also called "heat rays" are given off by all warm objects. Infrared telescopes must be cold so that their own radiation doesn't swamp the infrared. GSFC is working on an infrared instrument for the Landsat Data Continuity Mission (LDCM) Thermal Infrared Sensor (TIRS), planned for a December 2012 launch. The TIRS sensors will be cooled using a cryocooler that is being qualified for use by GSFC.

•**X-rays.** The sensors for XRS, the X-Ray Spectrometer measure temperature changes induced by incoming x-rays. When the sensors are colder, the induced temperature changes are larger and easier to measure. GSFC is working on an Adiabatic Demagnetization Refrigerator (ADR) that will be used to cool the x-ray sensors on the Astro – H spacecraft that is scheduled for launch in 2013.

Opportunities for Partnership

The Cryogenics and Fluids Branch works with groups inside and outside of NASA, including industry, academia, and other government agencies. Some of the collaboration methods include:

•Coordinated development projects in which each group performs work separately but information and data are shared and both organizations benefit.

•Work performed by GSFC researchers in GSFC facilities with funding from the outside organization.

•Work performed in GSFC facilities by researchers from the outside organization.

For more information, please see the Cryogenics and Fluids Branch web site at:

http://cryo.gsfc.nasa.gov/

Space Shuttle Discovery lifts off from Kennedy Space Center. Advanced cryogenics research, currently underway at GSFC, may one day enable astronauts to conserve fuel and travel much farther, opening up new realms to space exploration.

There are many ways to partner with Goddard. For information on all the ways your organization can take advantage of Goddard's research and development capabilities, please visit the Innovative Partnerships Program Office's website at:

http://ipp.gsfc.nasa.gov/

Avionics and Communications Research

NASA's plans for future missions beyond low Earth orbit (LEO) present unique technology challenges related to avionics and communications. Difficulties include requirements to minimize size, weight and power, increased data rates at longer ranges, enhanced reliability, and operating in high radiation or extreme temperature environments, both low and high. Other challenges include: the desire for systems to expand as infrastructure is added at remote locations such as the Moon, Mars, or near-Earth objects (NEOs); intelligent systems with the capability to operate autonomously and resolve failures without human intervention; common components and architectures which allow for growth and enhancement as new components or software are available; "reuse" of components once a mission phase is completed or as an "in situ" resource or spare. The architecture should support varying degrees of system reliability based on mission requirements ranging from single string high risk to complex and extremely reliable human rated systems.

Goddard Space Flight Center (GSFC) has a long and successful history developing avionics and communication systems in support of manned and unmanned NASA missions. Under the Exploration Systems Project, GSFC is leading the development of the avionics architectures and communications technologies that will be the core for future Exploration missions. Study of future Exploration missions and related requirements has led the avionics team to conclude that a distributed architecture provides a highly effective and efficient solution to diverse needs that have been identified.

Distributed Integrated Modular Avionics

The Avionics team (consisting of engineers from several NASA centers) is working to bring new approaches to avionics moving away from the centralized computer and software systems of the past and adopting a Distributed Integrated Modular Avionics (DIMA) architecture. GSFC is applying its experience in development of spacecraft software and communications to address the problems of developing a reliable, consistent, and coherent C3I (communications, command, control and information) architecture. The current development work is using the Altair Lunar Lander as the prototype for an implementation of the overall architecture but the concepts being advanced are applicable to any complex, high-reliability system. According to avionics engineer Tom Kenney, "NASA is uniquely positioned to establish the standards that will provide a foundation for future flexible and efficient avionics systems for applications in low earth orbit and beyond."

The distributed avionics architecture will play a vital role in enabling reliable operations for future missions. A distributed system breaks up the avionics into localized controllers, responsible for local functions such as propulsion, communications, instrumentation, power distribution, etc. These local controllers host modular software dedicated to supporting those local functions. In order to enhance reliability, these local controllers default to a contingency mode in the event of a loss of communication with the flight computers. Using these systems it is possible to have independent diverse backups to primary systems, addressing potential common mode failures. These techniques have possible applications to critical terrestrial infrastructure, including electrical grids, communications, air traffic controls systems and many others.

Thomas M. Kenny

Code: **599**

Years with NASA: **8**

Field of research: **Avionics**

Birthplace: **Bellefonte, PA**

Education: **BS Electrical Engineering; MS Electrical Engineering**

The system is integrated in that local controllers can interface with multiple subsystems that are isolated via hardware and software barriers so that a failure in one subsystem does not propagate to another. System elements must also support the integration of pretested components into a large system with no effect to the operation of existing elements. This composability reduces the time spent in system integration and test by leveraging testing at the subsystem level. This approach also enables system expansion, incorporation of intelligence as required, and the capability for self-healing in case of component failures. These capabilities, if used in commercial applications, could allow maintenance and upgrades of public utilities and information systems while minimizing the impact to necessary services. It also limits the impact of failures within these systems.

The planned modular avionics architecture is also extensible. As new elements are added they will benefit from the existing hardware/software library. This will allow new capabilities and features to be incorporated as technology evolves, and also allows for reuse of applications and components across numerous diverse systems and will reduce development and test related costs for future NASA projects. The avionics architecture being

An artist's rendering of the Altair Lunar Lander. Avionics engineers at GSFC are using the Altair Lunar Lander as a prototype for implementing their Distributed Integrated Modular Avionics (DIMA) architecture.

developed will be a critical enabling technology for efficiently and reliably conducting future missions.

The DIMA architecture has advantages for both NASA exploration and terrestrial applications. The use of distributed avionics can efficiently integrate real-time navigation information with communications systems for control of a spacecraft and related systems. These enhancements in future avionics architecture implementations will enable many of the communications technologies described below, such as smart radios, disruption tolerant networks, adaptive antenna systems, and IP protocols. The use of these modular systems also improves overall system reliability by preventing a fault in one subsystem from bringing down other subsystems, all while accomplishing the goal of reducing spacecraft mass.

The same architecture that allows reliable and efficient development of spacecraft has advantages for the initial implementation of infrastructure for robotic and human missions and could be applied to public and commercial systems. Possible applications include management and control of transportation, communications, energy distribution networks, and related components. Applying DIMA architecture techniques could reduce the cost of implementing and maintaining these systems as well as enhance the reliability of critical public infrastructure.

Disruption Tolerant Networks

To automate and make the communications operations robust, NASA GSFC is evaluating the application of disruption tolerant networking (DTN). As the name implies, these networks continue to function during delayed or disruption events that could cause a break in transmission on a normal space/ground network. DTN technology is critical to improve operations, such as spacecraft-to-ground link handovers, and to ensure reliable command, control, and communications for manned and unmanned research in areas where the terrestrial IP network falls short.

Their utility back on Earth is obvious, where network outages happen frequently. DTNs can serve a variety of critical applications (such as medical and disaster response communications), where network automation, reliability, and data integrity are essential.

The Communications Standards and Technology Laboratory (CSTL) is used to support the investigation, development, and demonstration of new communications standards and technologies.

Adaptive Antennas

Adaptive antennas use multiple antenna arrays to improve coverage and gain compared to single phased array antenna or omnidirectional antenna switching. An adaptive antenna coordinates control/phasing and uses sophisticated signal processing to array multiple smaller phased array antennas into a single unit. The result is expanded antenna coverage and superior performance with link availability, margin, and data rate. Adaptive antennas also may be able to reduce power requirements.

It is also possible to incorporate multi-band array technology into an adaptive array antenna system that supports S, X, and Ka-band operation. This can eliminate the need for a separate antenna to support high-speed Ka-band communications, reduce the mass of the vehicle antenna system, and significantly improve communications availability, data rates, and coverage.

Radiation Hardened Components

"Radiation hardened components have broad applications for future Exploration missions," according to Don Whiteman, Electronics Engineer, "with the potential for playing mission-critical roles such as communications, navigation, avionics, sensors, and data processing." They may also be useful in radiation-affected environments such as nuclear power plants and fusion research projects. Within communication system modulators and demodulators, radiation hardened chipset technology could increase data rates and offer the basic technology for the implementation of cognitive radio systems.

Don Whiteman

Code: **567**

Years with NASA: **12**

Field of research: **RF Communications**

Birthplace: **Ohio**

Education: **BS Electrical Engineering; MS Electrical Engineering**

IP Protocols

Goddard has supported the development of NASA Command, Control, and Communications (C3I) standards. Studies and demonstrations of C3I standards have been conducted between Goddard and other NASA centers. Such standards can help extend "the internet into space" by leveraging IP-based protocols to develop an interoperable architecture for space-to-ground and space-to-space communications. These standards can also further promote the concept of "plug-and-play" among various suppliers of space hardware and software.

Optical Communications

Optical communications technology is ideal where line of sight or fiber transmissions are possible. In space, terrestrial problems such as moisture, smoke, and haze are not issues, so optical is particularly well suited for communications outside the atmosphere. "You can transmit significant amounts of data through optical, literally orders of magnitude more than RF," explains Don. "The optical spectrum is currently unregulated, and the risk of interfering with other ground-based systems is very low." At present, Goddard is leading NASA's only in-space optical communications demonstration, leveraging the expertise and experience of its Optical Project Office to develop the ability to conduct optical vs. RF studies to determine the engineering advantages and trade-offs of each. Optical links are attractive for dry and cloud free environments, such as the U.S. Southwest, or where power and distances can be balanced to allow for transmission despite less than optimal atmospheric conditions. One example is communication between power generation units, such as solar fields and wind farms. They are also a low cost, wireless, high-bandwidth option for easy to establish primary links that can be backed-up with wireless redundancy. "There are lot of things you can do with optical," states Don. "For instance, the high bandwidth is ideal for sending imagery data to people on it. You can transmit satellite imagery for environmental monitoring and analysis. Any applications that require high bandwidth can take advantage of this technology." GSFC is also investigating the possible application of optical communication systems to support navigation for future missions.

Test and Evaluation for Communication Technologies

To stay at the cutting edge of space communications GSFC has developed the infrastructure needed to test and evaluate its inventions and products. For example, Goddard can leverage its stable of communication simulation and analysis facilities and tools such as the Communications Standards and Technology Laboratory (CSTL), the Goddard Electromagnetic Anechoic Chamber (GEMAC), High-Frequency Structure Simulator (HFSS), General Reflector and Antenna Far Field Analysis Software Program (GRASP), and various integrated suites of physical modeling tools including orbit generation and communications protocol simulation tools.

Opportunities for Partnership

Both in space and on Earth, the world of communications is rapidly evolving from land-line based systems to wireless and open path systems. Goddard Space Flight Center has been a leader in robust, high reliability, low weight and low power consumption optical and RF communications. GSFC's vast capabilities in the field of communications technology can be tapped through cooperative R&D and product development. For more information on how you can work with GSFC's expert communications engineers, please visit the Innovative Partnerships Program Office's website at:

http://ipp.gsfc.nasa.gov/

Related Facility Highlight

Goddard Space Flight Center has recently opened a new Optical Calibration Laboratory (OCL). Outfitted with state-of-of-the art plasma and laser-based light sources, the OCL will be dedicated to optical calibration and instrument development. The OCL's entirely detector-based calibration scheme utilizes NIST-traceable radiometers, as well as a 7ft. x 13.5ft. thermal vacuum chamber which is certified to handle space flight hardware.

Goddard is now seeking partnerships with organizations to utilize this new facility. Among the many potential industry applications for the OCL is developing free space optical communications systems for both space and terrestrial applications.

To inquire further about the OCL's capabilities or scheduling availability, please contact Brendan McAndrew, Code 551, at 301-286-8532, or brendan.mcandrew@nasa.gov, or visit the OCL's website at:

http://istd.gsfc.nasa.go/optics/facilities/OCL.html

For more information on partnerships and how to partner with this or any other of Goddard's cutting-edge research facilities, please email

techtransfer@gsfc.nasa.gov

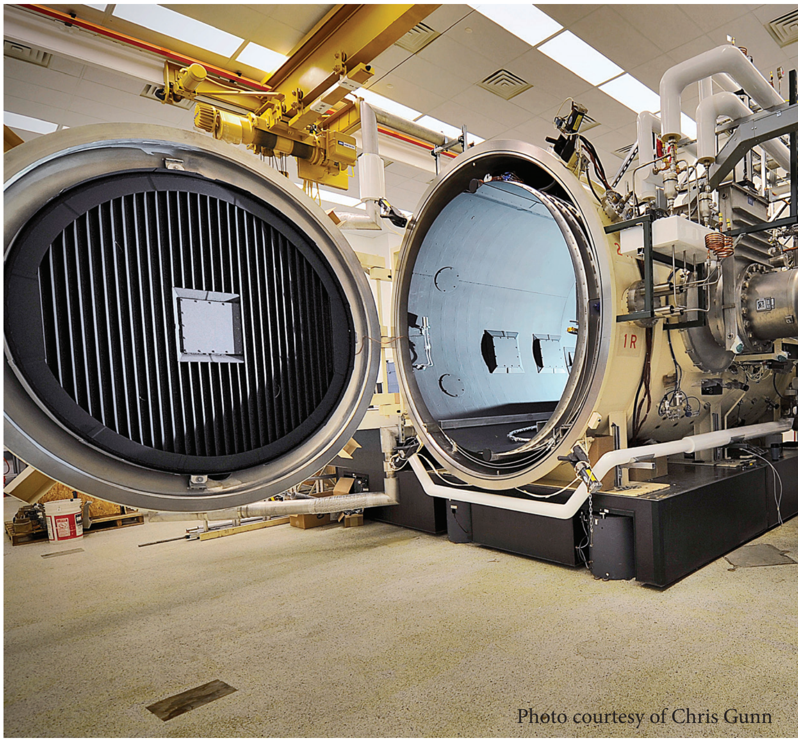


Photo courtesy of Chris Gunn

Thermal vacuum chamber at Goddard's new Optical Calibration Lab in Greenbelt, Maryland.

Compatability Tools for Space Hardware Development

NASA missions involve a wide variety of components provided by many different vendors. Some of these components are specific to the mission for which they were designed, while others could at least in theory be reusable for other missions. However, for these components to be successfully integrated into a secondary application, they must be able to communicate with any number of other components which they were not originally intended to interface with. If they do not communicate properly, this can lead to a system malfunction or even failure – despite the fact that all individual components may each be functioning perfectly.

This is not a problem relegated to space missions, of course. There are numerous terrestrial applications, such as sensor and detection networks, security systems, "smart grid" control systems, and others – where disparate hardware and software components all need to communicate seamlessly, with no interruptions or loss of data integrity.

Distributed System Integration Lab Communications Adapter Set (DSILCAS)

To address the issue of communications compatibility, a Goddard team, headed by Program Manager Tom Jackson, has developed the Distributed System Integration Lab Communications Adapter Set (DSILCAS). DSILCAS (GSC 15501-1)uses standard IP networking to connect geographically distributed components, which natively use non-IP communication busses, protocols, and interfaces (for example LVDS, 1553, CCSDS AOS). This makes each component appear to the others as if they were directly linked via wired connection. Therefore inter-component functional testing can be performed even though the test units themselves may be in separate buildings, on the same campus, or on different continents.

The DSILCAS system consists of two independent but associated elements. The DSIL Interface Unit's (DSILIU) (GSC 15847-1) primary function is to transfer non-IP data (discrete signals, raw Ethernet, RS-485, RS-422, and radio bitstreams) over an IP network, to another DSILIU. Whatever goes in one DSILIU comes out the other side of another DSILIU, reliably and in order. The DSILIU encapsulates user data in a TCP/IP connection suitable for transmission over a WAN.

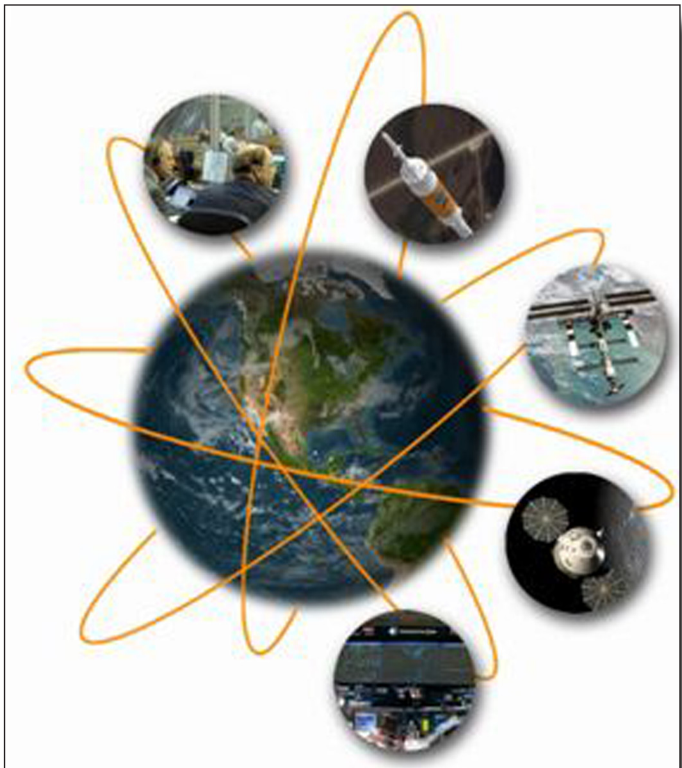
The second component is the DSIL Communication Adapter (DSILCA) (GSC 15846-1) which is used as a media converter between IP and link layer protocols. Data can be transmitted from a local or remote system via TCP or UDP, converted to raw Ethernet, encapsulated/encoded into radio bitstreams, and used to set or clear discrete signals.

DSILCAS converts non-C3I compliant data and interfaces into C3I compliant data/interfaces to provide interoperability between systems. DSILCAS operates independently of Internet Protocol (TCP/UDP/RTP/etc.) and transmits raw Ethernet frames. By using the DSILCAS hardware, risks, and costs will be reduced significantly, as it allows each vendor to connect their flight interface to another flight interface remotely. This allows for early interface verification, system integration, and validation.

Gold Standard Test Set (GSTS)

The Gold Standard Test Set (GSTS) (GSC 15873-1)is a turn-key software/hardware solution that offers the ability to quickly and easily verify a system's compliance with a selected subset of the C3I standard. The GSTS verifies communications protocols between systems via a simple but powerful X-Windows based GUI and pre-defined test scripts. Using the powerful built-in protocol analysis features and custom packet-processing facilities, users can capture, monitor, filter, and manipulate the data packets and frames ingested by the GSTS. In this way, GSTS provides a level of protocol insight and manipulation previously unavailable for space-based communications testing.

Test scripts are focused primarily on verification of network requirements for flight vehicles and C3I data exchange protocols. Note that these scripts can be adapted to test for many other protocols. According to Tom, these can include a variety of industry standard communication protocols used by various hardware/software networks. This allows for a component to be tested against a specific protocol, with a report indicating whether or not the unit is in compliance, and, if not, what non-compliant areas need to be addressed. This can ensure that all network components are in 100% compliance before they are added to a network, thereby avoiding incompatibility issues



that may not manifest themselves until the full network is in operation. Such a capability would have obvious value to a variety of commercial, research, and military networks and systems – for example, a new sensor or meter could be tested for compliance before it is incorporated into the network.

Takeaways

DSILCAS allows users to use real flight interfaces early and often (raw Ethernet, radio framing, and so on). There is also no need for vendors to adapt their systems to less flight-like configurations for distributed development and testing. And since DSILCAS simulates co-located equipment with one platform, there is no need for multiple media converters.

GFSC testing with DSILCAS has demonstrated:

- Transport of Ethernet, AOS and serial data between far-flung, geographically distributed systems
- Use of existing WAN IP infrastructure
- Validation of protocol and system implementations
- Successful integration of systems

Developing and deploying the DSILCAS systems have provided the GSFC team with extensive experience in NASA's C3I standards, IP networking, and DSNET communications. These "lessons learned" can now be applied wherever there is need for administrators and designers of large, complex network architectures to ensure new components will be 100% in compliance with its communication protocols – before a system failure identifies the problem for them. ■

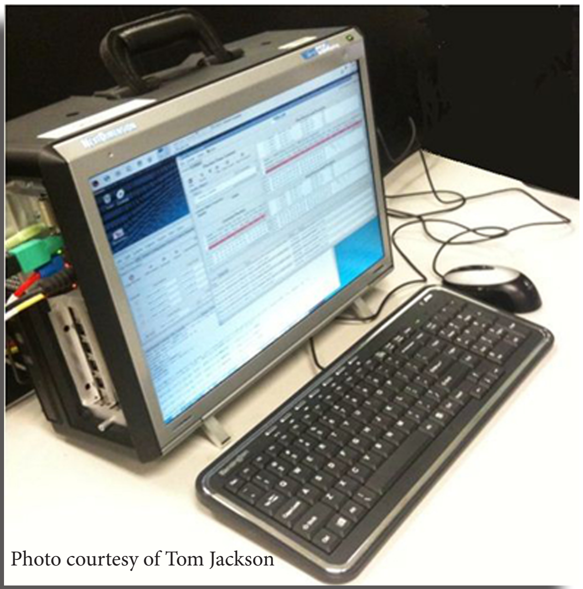


Photo courtesy of Tom Jackson

The GSTS hardware itself is housed in a ruggedized portable enclosure, which contains multiple Gigabit Ethernet, LVDS/RS-422 radio, and IRIG-B interfaces.

Available Goddard Technologies

The following technologies mentioned in this article are available for use by other NASA centers or government agencies under a Software Usage Agreement:

- Distributed System Integration Lab Communications Adapter Set (GSC 15501-1)
- Distributed System Integration Lab Interface Unit (GSC 15847-1)
- Distributed System Integration Lab Communications Adapter (GSC 15846-1)
- Gold Standard Test Set (15873-1)

For information on how to set up a Software Usage Agreement with Goddard Space Flight Center, please visit the Innovative Partnerships Program Office's website at:

http://ipp.gsfc.nasa.gov/

Tom Jackson

Code: **581**

Years at GSFC: **25**

Field of research: **Dynamics Simulators, Software Development and Testing Methodologies**

Birthplace: **Baltimore, MD**

Education: **BS Physics**

GPS Navigation on the Moon

Whether you're the captain of a cruise ship heading for your next port of call or just a hungry driver looking for that great new restaurant opening across town, navigating the surface of the Earth is a problem we've all had experience with. It's not a new problem. Over the centuries people have come up with all manner of devices and methods to help calculate where they are and where they are going.

The latest and most powerful solution to this problem employs a hand held receiver that uses timing signals from a fleet of satellites to compute position and velocity; the Global Positioning System or GPS. But what do you do on the surface of the Moon, or Mars, or even an asteroid where there is no satellite system to rely on? Can we adapt ancient methods to solve the modern problem of navigating on the surface of another celestial body without the risk and expense of a large infrastructure?

The answer is a resounding yes. One of the most powerful of classical navigation instruments was the Astrolabe. Although its exact origins have been lost to history, we do know that it was invented in Greece, developed and perfected by 8th century Islamic Astronomers, and eventually adopted by Christian Europeans sometime in the 13th century. The Astrolabe worked by allowing a user to compare the stars visible in the sky to a reference book of star charts. From this, the navigator could work out the approximate time of the observation, as well as the only location on the surface of the Earth where those stars would be visible at that time.

A late 16th-century Astrolabe.

To address the problem of celestial navigation without GPS support, Goddard engineers modernized this medieval method using 21st century technology. The result of this work was the creation of LaNDS (Lunar Navigation Determination System) (GSC 15892-1). Though it was designed specifically for the moon, the concept can be adapted with relative ease for use on the surface of any celestial body in the Solar System where the stars are detectable. Two principal software components, also developed by Goddard, have been integrated to create LaNDS: ILIADS (Integrated Lunar Information Architecture for Decision Support) (GSC 15339-1, GSC 16209-1, GSC 16210-1) and GEONS (GPS-Enhanced Onboard Navigation System) (GSC 14687-1). ILIADS is a lunar Geospatial Information System (GIS) that provides users with the ability to locate, access, quantitatively analyze, visualize, and interact with

Hand-held LaNDS used as a portable map and direction finder.

Image courtesy of Oskar Daniel and Tomas Johansson, Lund Institute of Technology / Lund University)

multiple, superposed layers of mapped lunar surface data. Representative data layers that can be rendered by ILIADS are: surface albedo, 3D terrain, and science data (e.g., mineralogy, hydrogen). In addition, time-varying information (e.g., lunar surface illumination) and derived analyses (e.g., surface roughness derived from lunar topography data sets) can also be produced and rendered. Taking advantage of its extended Kalman filter, GEONS is used to compute both position and heading information for stationary and mobile (e.g., rover) lunar surface assets.

An integrated star camera provides information enough to determine the inertial attitude of the device while a built in gravity sensor simultaneously detects the local horizontal. This in combination with advanced ephemeris, mapping, and topographic information from the integrated ILIADS / GEONS system software allows LaNDS to compute and display the user's surface position and heading in the context of a map stored on the device.

As if that weren't enough, it can also show the location of any emplaced assets (e.g., rovers, landers, outposts or safe havens in the event of solar storms), and identify potential terrain hazards (e.g., craters, rilles) and illumination cycles the user cares to store in its memory. The LaNDS concept offers the potential to do all this without relying on communications or information from any external sources, but could be constructed to provide improved performance by accepting reference data from any available sources. Independence and flexibility makes the hand-held LaNDS an ideal safety device in the event astronauts find themselves in a contingency situation where other navigation references have either failed or are unavailable.

The first step in making this a reality was accomplished by Goddard engineers in 2009. An Earthbound proof-of-concept experiment was successfully developed using the commercially available Celestron SkyScout to create data needed to test Goddard's Celestial Navigation (CelNav) algorithms (GSC 14679-1). Normally, the SkyScout uses a built-in GPS receiver to determine the user's position and a gravity sensor to establish the orientation of the unit on the surface. It does this in order to compute where the unit is pointed in inertial space, and therefore what star the user is observing. LaNDS is designed to actually to solve the reverse problem, that is establishing position once the star pattern has been identified. To test the concept, Goddard engineers in cooperation with the inventor of the SkyScout created an interface to a laptop that uses the "truth" solutions from the SkyScout to construct outputs that would be expected from a star camera/gravity sensor combination. Those solutions are then fed to another laptop standing in for LaNDS. The second laptop gets only that data it would get from a star camera/gravity sensor combination and uses it to compute location. The solution can then be compared to the original GPS output of the SkyScout.

In order to successfully complete a functioning demonstration of the LaNDS concept, Goddard engineers had to integrate CelNav, GEONS and ILIADS software. This proving out of the LaNDS concept demonstrates that as NASA redefines and solidifies future exploration plans to send humans to distance worlds, Goddard will be there, ready to show the way. ■

Available Goddard Technologies

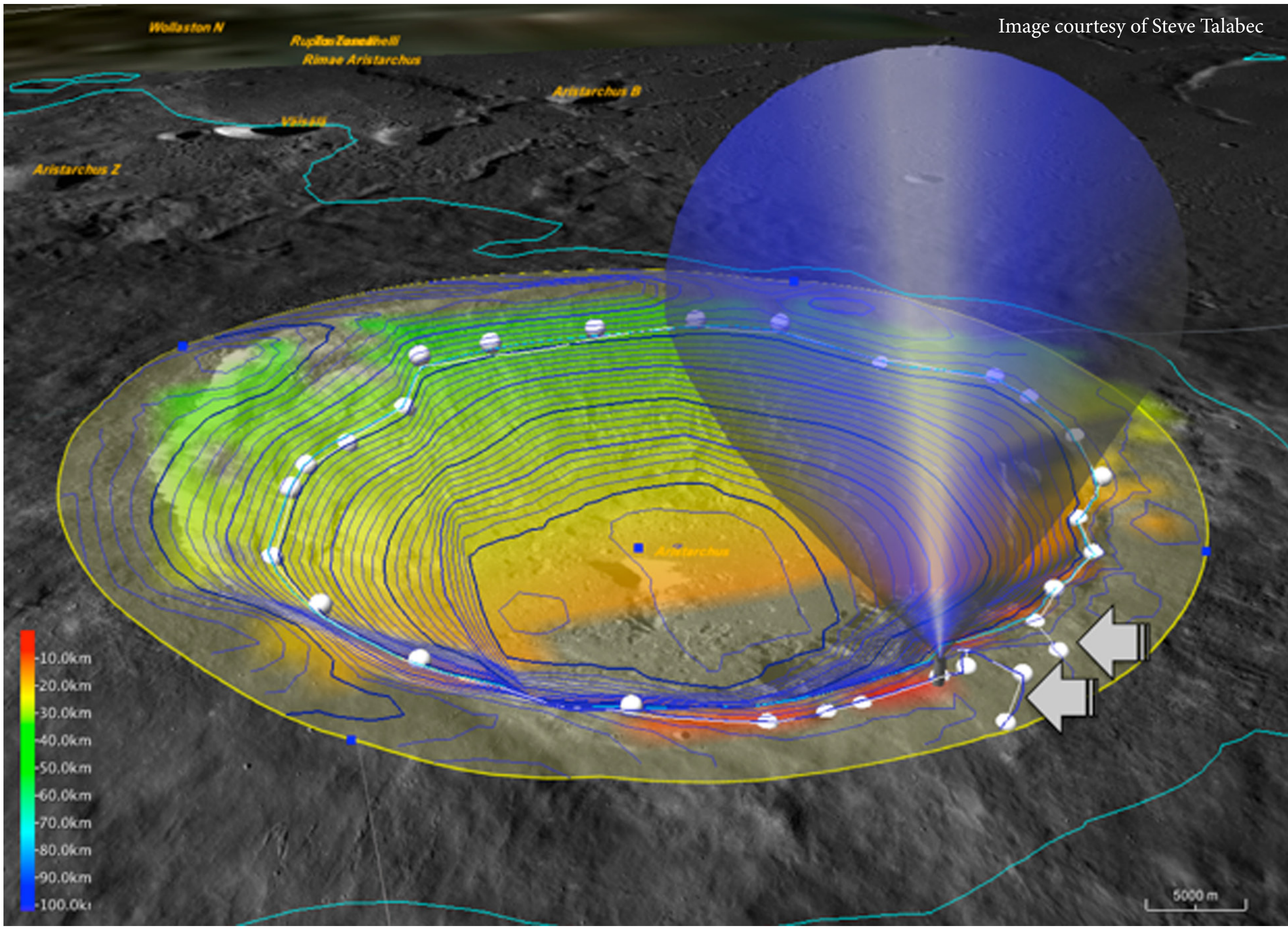
The following technologies mentioned in this article are available for use by other NASA centers or government agencies under a Software Usage Agreement:

- Lunar Navigation Determination System (GSC 15892-1)
- Integrated Lunar Information Architecture for Decision Support (GSC 15339-1, GSC 16209-1, GSC 16210-1)
- Celestial Navigation (CelNav) (GSC 14679-1)

The GPS-Enhanced Onboard Navigation System (GSC 14687-1) is also being made available to any organization via license.

For more information on how to use these or any other Goddard Technologies, please visit the Innovative Partnerships Program Office's website at:

http://ipp.gsfc.nasa.gov/



This screen capture depicts ILIADS performing on-the-fly geospatial analysis of the impact crater Aristarchus. The white dots represent a hypothetical traverse path around the crater created by ILIADS' Path Planner Tool. This path has been chosen because it will allow the crew and vehicle to remain within line-of-sight communications with the antenna. (Antenna not to scale)

Staff from IPP Office attended several events in Summer 2010

Public Service Recognition Week
(May 6-8, on the Mall in Washington, D.C.)

Celebrated since 1985, Public Service Recognition Week (PSRW) is a nationwide public education campaign honoring the men and women who serve our nation as federal, state, county, and local government employees and ensure that our government is the best in the world. From the steps of the Capitol to the smallest towns, public servants use the week to educate citizens about the work that they do and why they have chosen public service careers. Throughout the week, communities take this occasion to host events from open houses to parades recognizing and thanking their local unsung heroes. The capstone celebration is held every year on the National Mall, with more than 100 civilian and military agencies, nonprofit organizations, and private companies sponsoring interactive and educational exhibits that showcase the innovative and quality work performed by public employees.

A child explores the NASA @ Home & City interactive application at the Public Service Recognition Week on the Mall in Washington D.C. on May 7, 2010 that demonstrates how spin-off technologies are used every day in his community.

GSFC SBIR/STTR Program Manager Dr. Stephen Rinehart speaks to small businesses about the importance of technology development, business success, and utilization of their technologies via infusion (internal NASA use) and commercialization (technologies to the marketplace).

Next Steps in Managing Innovation Workshop
(May 12, Doubletree Guest Suites Philadelphia West in Plymouth Meeting, PA)

The Next Steps in Managing Innovation Workshop was designed to help SBIR companies advance in their Technology Readiness Levels (TRLs) in order to license and commercialize their technologies. NASA's IPP office works with businesses to develop advanced technologies to benefit NASA as well as impact commercial industry. This workshop gave businesses the opportunity to learn about avenues for partnership and about the specific technology needs of GSFC and other resources for company and technology development. Highlights for small businesses that attended included: networking with prime contractors, one-on-one meetings with GSFC Associate Chief Technologists, and panels on IP management and additional partnership resources.

Science Jamboree
(June 2, on the Goddard Mall)

The Sciences and Exploration Directorate's laboratories, branches, and offices showed off their science to the entire Goddard Space Flight Center community. Highlights of the Jamboree included: live science experiments, show-and-tell, and displays; Science Cafe seating area for chatting with colleagues, old and new; cajun lunch available for purchase; free afternoon refreshments. This was a chance to meet people in other directorates, learn about their work, and cross-pollinate ideas for interdisciplinary research. It's also a unique learning opportunity for summer interns and newly arrived scientists.

The Innovative Partnerships Program Office finds a festive way to display their Partnerships and SBIR/STTR brochures at the Mardi Gras themed Science Jamboree.

A Celebrate Goddard Day attendee explores the AETD Table Satellite demonstration to learn about how GSFC's spin-off technologies unite the world.

Celebrate Goddard Day
(June 24, on the Goddard Mall)

This year's event featured entertainment provided by Goddard colleagues, Directorate exhibits, a car show, a talent show, tours, diverse food, and the first-ever Celebrate Goddard Parade. This annual event is designed to highlight the diverse skills and individual differences that have made our success possible. The Goddard Mall was filled with opportunities to learn more about the many parts that make up the Goddard mission. Many of the clubs that make up the Goddard community were on the Mall as well to share information on their activities, giving demonstrations under the main tent, and welcoming new members.

Technology Innovation and Technology Transfer Training
(June 29, Goddard Building 1)

Ted Mecum primarily (and Dale Clarke to a smaller extent) conducted this training which gave Goddard employees information about the IPP office, the technology transfer process, IP management (and spinning technology out of NASA) as well as technology infusion (spinning technology or capabilities into NASA). The course also covered why technology transfer is important and how to submit New Technology Reports (NTRs). ■

Ted Mecum, Technology Manager for Code 504, teaches innovators at GSFC how to submit a New Technology Report at the Technology Innovation and Technology Transfer Training.

Tech Transfer Metrics Third Quarter of FY10

metrics

New Technology Reports: 70

Furuno Radar/SureTrak Interface Software by Ted Daisey (Code 589)

Refinement of the HSEG Algorithm for Improved Computational Processing Efficiency by James Tilton (Code 606.3)

ITOS v.8.0 by Barbara Milner (Code 583)

Citizen Science Grid by Michael Seablom (Code 610.3)

GMSEC ANSR 3.9.1 by Peter Hitchner (Emergent Space Technologies, Inc.)

Cryogenic Compatible Winchester Connector Mount and Retaining System for Composite Tubes - Adhesive Free by James Pontius (Code 542)

Nanostructure Secondary Mirror Apodization Mask for Transmitter Signal Suppression in a Duplex Telescope by John Hagopian (Code 551)

Digital Signal Processing / Field Programmable Gate Array Design (Logic and Code) for a High Speed Programmable S-Band Space Transceiver by Jeffrey L. Janicik (Innoflight, Inc.)

Ridge Waveguide Structures in Magnesium-Doped Lithium Niobate by Phil Himmer (Univ. of Montana)

Hierarchical Image Segmentation Algorithms on Space-based Reconfigurable Computing Platforms by Kevin Fisher (Code 587)

A Data Acquisition Architecture for Characterizing the Performance of Solar Imaging Systems by Udayan Mallik (Code 564)

Validating Computational Correctness using Hash Equivalent Algorithmic Transforms (HEAT) by Karin Blank (Code 586)

Telemetry and Science Data Software System by Ling Hong (SAIC)

Multiplexing X-ray Fluorescence (MXRF) by Richard Koenecke (Code 660)

A Gamma Ray Burst Polarimeter Data Acquisition System by Udayan Mallik (Code 564)

Radiation Hard Space Wire/ Gigabit Ethernet Compatible Transponder by Vladamir Katzman (Advanced Science and Novel Technologies)

Scalable Integrated Multi-Mission Support System (SIMSS) Simulator Release 2.0 for GMSEC (Goddard Mission Services Evolution Center) by John Kim (Honeywell Technology Solutions)

Carbon Nanotube-based Thermal Interfaces for Thermal Switching Applications by Jay Rozzi (Creare)

Scalable Integrated Multi-Mission Support System (SIMSS) Simulator Release 3.0 for GMSEC (Goddard Mission Services Evolution Center) by John Kim (Honeywell Technology Solutions)

Methodology of Evaluating Margins of Safety in Critical Brazed Joints by Yury Flom (Code 541)

Composite with In-Situ Plenums by Mark Montesano (k-technology.com)

A Near-Infrared Photon-Counting Camera For High Sensitivity Astronomical Observations by Michael Jurkovic (Intevac, Inc.)

Hybrid High-Temperature Superconducting Current Leads for Space Applications by David Hilton (Tai-Yang Research Company)

Advanced Turboalternator for Cryogenic Refrigeration by Jeffrey Breedlove (Creare)

Space Plasma Alleviation of Regolith Concentrations in Lunar Environments by Discharge (SPARCLED) by Steven Curtis (Code 695)

Using Fiber and Photonic Crystal Fiber (PCF) Techniques to Build Novel Planar Waveguides (PWG) by Betsy Pugel (Code 554)

SAM Flight Software by Tom Nolan (Nolan Engineering, LLC)

SAIC Algorithm Testbed for Asteroid Detection (SALTAD) version 1.5 by Peter Gural (SAIC)

Grazing Incidence Ultra-Thin Composite Slab Laser and Amplifier by Steven Li (Code 554)

GEOS2WRF and MERRA2WRF: Tools for Processing GEOS5 and MERRA Atmospheric Data for Input into the WRF Model by Eric Kemp (Northrup Grumman)

Photodetector with Nanowire Photocathode by Keith Shoemaker (Physical Optics Corporation)

Modular Autonomous C&DH Software with Built-In Simulation/Test by John Cueseo (Advanced Solutions, Inc.)

Building Blocks for the Rapid Development of Parallel Simulations by Brian Granger (Tech-X Corporation)

Sensor (TIRS) Instrument on Landsat Data Continuity Mission (LDCM) by James D. Trolinger (MetroLaser, Inc.)

Development of a Focal Plane Front-End Electronics Based on Teledyne's SIDECAR Application Specific Integrated Circuit (ASIC) Chip for the Thermal Infrared by Peter Shu (Code 553)

Super Resolution Multi-Dimensional Interferometer by Nils Straatveit (SeeSignals, LLC)

(SensorWeb)Campaign Manager API Client by Patrice Cappelaere (Vightel Corporation)

NBL Pistol Grip Tool (NPGT) - A Light Weight Version of the PGT Used in Underwater Training of NASA Astronauts by Michael Liszka (ATK)

A Micro-Force Sensing Nano-Probe by Ryan McClelland (SGT)

Interlocking Modular Cargo Pallet System by Andrew Jones (Code 543)

Space Operations Learning Center (SOLC) by Ben Lui (Code 581)

SureTrak Probability of Impact Display by John Elliott (Code 589)

Integrated Trending and Plotting System (ITPS) Tool Archives, Extracts and Analyzes Spacecraft Housekeeping Telemetry Data (GMSEC R3.0) by Haim Brumer (Honeywell Technology Solutions)

Scenario Scheduler Timeline Execution Application Suite by Jim Busch (Code 583)

Self-Aligning Grip for Fiber Testing by Walter B. Thomas (Code 500)

Cross Support Transfer Service (CSTS) Framework (User Side) Software Library by Timothy Ray (Code 583)

Asynchronous Message Service (AMS) Software Libraries by Timothy Ray (Code 583)

Asymptotic Diet Algorithm with Psychological and Temporal Stability (ADAPTS) by Steven Curtis (Code 695)

The James Webb Space Telescope/National Polar-Orbiting Operational Environmental Satellite System- Portable Spacecraft Simulator (JWST/NPOESS-PSS) by Arthur Kong (Code 583)

Dust Devil Electron Avalanche Model (DDEAM) by Telana Jackson (Code 695)

GSFC Mission Services Evolution Center (GMSEC) Parameter Display by Vuong Ly (Code 583)

GSFC Mission Services Evolution Center (GMSEC) Compliance Test Suite by Vuong Ly (Code 583)

Temperature Dependences of Mechanisms Responsible for the Water-Vapor Continuum Absorption by Qiancheng Ma (GISS)

Coordinated Data Analysis Web (CDAWeb) + by Reine Chimiak (Code 587)

Near-Field Amplitude-Only Measurement System to Measure Performance of mm-Wave Antennas by Manohar Deshpande (Code 555)

Fault Tolerant, Radiation Hard OSP by PJ Ellison (Spacemicro)

GMSEC API Performance Testing Utility by Vuong Ly (Code 593)

Pandora Operation and Analysis Software by Jay Herman (Code 613)

A Smooth-Walled Feedhorn with sub 30 dB Cross-Polarization Over a 30% Bandwidth by Edward Wollack (Code 665)

Interface Validation for Distributed Software Systems by Pavan Rajagopal (GeoControl Systems)

Light-Weight Workflow Engine: A Server for Executing Generic Workflows by Shawn Freeman (Northrop Grumman)

Mirror Metrology Using Nano-Probe Supports by Ryan McClelland (SGT)

Photochemical Carbon Dioxide Sensor by John Bognar (Anasphere, Inc.)

Electrostatic Dust Removal Technique by Jun-ru Wu (Univ. of Vermont)

Blocking Filters With Enhanced Throughput for X-Ray Microcalorimitry by Jacob Betcher (Luxel Corp)

CCSDS Telemetry Decoder VHDL Core by Tom Winker (Code 587)

Moonbase Alpha Game Software by Daniel Laughlin (Learning Technologies)

Crosstalk Test Targets for Multiple Channel Laser Altimeters by Luis Ramos-Izquierdo (Code 551)

Methods of DNA Methylation Detection by Brian Filanoski (University of Idaho)

Multi-User Space Link Extension (SLE) System (also known as "MUS" and "Multi-User SLE") by Toby Perkins (Honeywell Technology Solutions)

Patents Issued: 4

Polarization-Preserving Waveguide Filter And Transformer by Felice Vanin (Code 555/Intern), Edward Wollack (Code 665)

A Split-Remerge Method for Eliminating Processing Window Artifacts In Recursive Hierarchical Segmentation by James Tilton (Code 606.3)

Systems, Methods & Apparatus For Implementation Of Formal Specifications Derived from Informal Requirements by Michael Hinchey (Code 585), James Rash (Code 588), Christopher Rouff (SAIC), Denis Gracanin (Virginia Polytechnic Univ.), John Erickson (Intern)

Joint Assembly by Katherine Strausser, Andrew Punnoose, Andrew Wilson (NASA Robotics Academy)

Patent Applications Filed: 3

Novel Superconducting Transition Edge Sensor Design by John E. Sadleir (Code 662)

Automatic Extraction of Planetary Image Features by Jacqueline LeMoigne-Stewart (Code 580), Giulia Troglio, Jon Benediktsson (Univ. of Iceland), Sebastiano Serpico, Gabriele Moser (Univ. of Italy)

Aerodynamically Stabilized Instrument Platform by Geoffrey Bland (WFF/ Code 614.6), Ted Miles (WFF/ Code 569)

Partnership Profiles

The IPP Office is pleased to announce the recent signing of several agreements.

Partner	Technology/Focus	Type	NASA Goals/Benefits
Emergent Space Technologies	GSFC Formation Flying Test Bed GPS test and simulation equipment	Space Act Agreement	This Amendment to the original Agreement is to extend the term another three years to allow Emergent access and use of the GSFC Formation Flying Test Bed GPS test and simulation equipment and facilities, on a non-competitive and after-hours basis, for commercial purposes.
Schneider Optics, Inc.	Cinegon 2.1/6mm Lens Design	Space Act Agreement	This Amendment to the original Agreement is to extend the term another two years and add a new lens design (Cinegon 2.1/6mm) to the list of design specifications being provided to GSFC in exchange for Images taken using the optics from space. The lens designs will support the design and analysis of associate stray light baffle hardware for use in several upcoming technology demonstration flights to the International Space Station.
Air Force Research Lab (AFRL)	Massive Heat Transfer Experiment (MHTEX)	Space Act Agreement	The purpose of this agreement is to support the AFRL Massive Heat Transfer Experiment (MHTEX) by providing the AFRL with NASA hardware (the Two-Phase Flow (TPF) Thermal Control Flight Experiment flown by NASA GSFC in 1997) for modification and re-flight aboard the International Space Station (ISS).
ATK Space Systems	Slosh Dynamics of a Plexiglass Propellant Tank	Space Act Agreement	NASA GSFC and ATK Space Systems will make available and store a plexiglass propellant tank at ATK for future dynamic slosh testing throughout the propulsion community. NASA GSFC and ATK Space Systems will also collect and store all technical data on slosh dynamics for use by the entire propulsion community.
University of Southern California's Information Sciences Institute (USC ISI)	On-Orbit Radiation Hardened Software Technologies	Space Act Agreement	A Non Reimbursable Space Act Agreement has been established between NASA GSFC and the University of Southern California's Information Sciences Institute (USC ISI). This agreement will help to augment and accelerate NASA's ongoing development efforts in the area of on-orbit radiation hardened software technology while, at the same time, allowing USC ISI to demonstrate their flight ready experiments that can be uplinked to the on-orbit SpaceCube v.1 board demonstration platform on board of the International Space Station
University of Baltimore's Merrick School of Business	Lab to Market Program	Space Act Agreement	The IPP Office successfully negotiated a follow-on agreement between GSFC and the University of Baltimore's Merrick School of Business. The agreement allows GSFC IPP Office to participate in the University of Baltimore's Lab to Market Program and educate students about NASA Goddard technology transfer practices. Additionally, students will have the opportunity to work with Goddard IPP by performing technology commercialization assessments and market studies of GSFC technologies. This will help GSFC IPP determine opportunities for pursuing licensing and partnership agreements.

Exploration
SystemsProjects

Goddard Tech Transfer News http://ipp.gsfc.nasa.gov

Chief: Nona Cheeks
(301) 286-5810
Nona.K.Cheeks@nasa.gov

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