TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technology Focus

Electronics/Computers

Software

Materials

Mechanics/Machinery

Manufacturing

Bio-Medical

Physical Sciences

Information Sciences

Books and Reports

INTRODUCTION

Tech Briefs are short announcements of innovations originating from research and development activities of the National Aeronautics and Space Administration. They emphasize information considered likely to be transferable across industrial, regional, or disciplinary lines and are issued to encourage commercial application.

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Tech Briefs

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Cloud Absorption Radiometer Autonomous Navigation System — CANS

The system captures navigational data in real time while keeping the sensor centered on a fixed target.

Goddard Space Flight Center, Greenbelt, Maryland

CAR (cloud absorption radiometer) acquires spatial reference data from host aircraft navigation systems. This poses various problems during CAR data reduction, including navigation data format, accuracy of position data, accuracy of airframe inertial data, and navigation data rate. Incorporating its own navigation system, which included GPS (Global Positioning System), roll axis inertia and rates, and three-axis acceleration, CANS expedites data reduction and increases the accuracy of the CAR end data product.

CANS provides a self-contained navigation system for the CAR, using inertial reference and GPS positional information. The intent of the software application was to correct the sensor with respect to aircraft roll in real time based upon inputs from a precision navigation sensor. In addition, the navigation information (including GPS position), attitude data, and sensor position details are all streamed to a remote system for recording and later analysis.

CANS comprises a commercially available inertial navigation system with integral GPS capability (Attitude Heading Reference System—AHRS) integrated into the CAR support structure and data system. The unit is attached to the bottom of the tripod support structure. The related GPS antenna is located on the P-3 radome immediately above the CAR. The AHRS unit provides a RS-232 data stream containing global position and inertial attitude and velocity data to the CAR, which is recorded concurrently with the CAR data. This independence from aircraft navigation input provides for position and inertial state data that accounts for very small changes in aircraft attitude and position, sensed at the CAR location as opposed to aircraft state sensors typically installed close to the aircraft center of gravity. More accurate positional data enables quicker CAR data reduction with better resolution.

The CANS software operates in two modes: initialization/calibration and operational. In the initialization/calibration mode, the software aligns the precision navigation sensors and initializes the communications interfaces with the sensor and the remote computing system. It also monitors the navigation data state for quality and ensures that the system maintains the required fidelity for attitude and positional information. In the operational mode, the software runs at 12.5 Hz and gathers the required navigation/attitude data, computes the required sensor correction values, and then commands the sensor to the required roll correction. In this manner, the sensor will stay very near to vertical at all times, greatly improving the resulting collected data and imagery.

CANS greatly improves quality of resulting imagery and data collected. In addition, the software component of the system outputs a concisely formatted, high-speed data stream that can be used for further science data processing. This precision, time-stamped data also can benefit other instruments on the same aircraft platform by providing extra information from the mission flight.

This work was done by Duncan Kahle of Goddard Space Flight Center, Charles Gatebe of the University of Baltimore, Bill McCune of Adaptive Aerospace, and Dustan Hellwig of Chesapeake Technology International. Further information is contained in a TSP (see page 1). GSC-16395-1

Software Method for Computed Tomography Cylinder Data Unwrapping, Re-slicing, and Analysis

Visualization of the data is possible in one view without having to rotate the volume rendering.

John H. Glenn Research Center, Cleveland, Ohio

A software method has been developed that is applicable for analyzing cylindrical and partially cylindrical objects inspected using computed tomography (CT). This method involves unwrapping and re-slicing data so that the CT data from the cylindrical object can be viewed as a series of 2D sheets (or flattened "onion skins") in addition to a series of top view slices and 3D volume rendering. The advantages of viewing the data in this fashion are as follows: (1) the use of standard and specialized image processing and analysis methods is facilitated having 2D array data versus a volume rendering; (2) accurate lateral dimensional analysis of flaws is possible in the unwrapped sheets versus volume rendering; (3) flaws in the part "jump out" at the inspector with the proper contrast expansion settings in the unwrapped sheets; and (4) it is much easier for the inspector to locate flaws in the unwrapped sheets versus top view slices for very thin cylinders. The method is fully automated and requires no input from the user except proper voxel dimension from the CT experiment and wall thickness of the part.

The software is available in 32-bit and 64-bit versions, and can be used with binary data (8- and 16-bit) and BMP type CT image sets. The software has memory (RAM) and hard-drive based modes. The advantage of the (64-bit) RAM-based mode is speed (and is very practical for users of 64-bit Windows operating

systems and computers having 16 GB or more RAM). The advantage of the hard-drive-based analysis is one can work with essentially unlimited-sized data sets.

Separate windows are spawned for the unwrapped/re-sliced data view and any image processing interactive capability. Individual unwrapped images and un-wrapped image series can be saved in common image formats.

More information is available at http://www.grc.nasa.gov/WWW/OptInstr/NDE_CT_CylinderUnwrapper.html.

This work was done by Don J. Roth of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18808-1.

Discrete Data Qualification System and Method Comprising Noise Series Fault Detection

Noise fault detector detects an unreasonably high or low variance or standard deviation.

John H. Glenn Research Center, Cleveland, Ohio

A Sensor Data Qualification (SDQ) function has been developed that allows the onboard flight computers on NASA's launch vehicles to determine the validity of sensor data to ensure that critical safety and operational decisions are not based on faulty sensor data. This SDQ function includes a novel noise series fault detection algorithm for qualification of the output data from LO_2 and LH_2 low-level liquid sensors. These sensors are positioned in a launch vehicle's propellant tanks in order to detect propellant depletion during a rocket engine's boost operating phase. This detection capability can prevent the catastrophic situation where the engine operates without propellant. The output from each LO_2 and LH_2 low-level liquid sensor is a discrete valued signal that is expected to be in either of two states, depending on whether the sensor is immersed (wet) or exposed (dry). Conventional methods for sensor data qualification, such as threshold limit checking, are not effective for this type of signal due to its discrete binary-state nature.

To address this data qualification challenge, a noise computation and evaluation method, also known as a noise fault detector, was developed to detect unreasonable statistical characteristics in the discrete data stream. The method operates on a time series of discrete data observations over a moving window of data points and performs a continuous examination of the resulting observation stream to identify the presence of anomalous characteristics. If the method determines the existence of anomalous results, the data from the sensor is disqualified for use by other monitoring or control functions.

This work was done by Christopher Fulton, Edmond Wong, and Kevin Melcher of Glenn Research Center; and Randall Bickford of Expert Microsystems, Inc. For more information, contact kimberly.a.dalgleish@nasa.gov.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18694-1.

Simple Laser Communications Terminal for Downlink From Earth Orbit at Rates Exceeding 10 Gb/s

Implementation of this technology will surpass the spectrum-allocation and bandwidth limitations of current RF systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact, low-cost laser communications transceiver was prototyped for downlinking data at 10 Gb/s from Earth-orbiting spacecraft. The design can be implemented using flight-grade parts. With emphasis on simplicity, compactness, and light weight of the flight transceiver, the reduced-complexity design and development approach involves:

1. A high-bandwidth coarse wavelength division multiplexed (CWDM) (4×2.5 or 10-Gb/s data-rate) downlink transmitter. To simplify the system, emphasis is on the downlink. Optical uplink data rate is modest (due to existing and adequate RF uplink capability).
2. Highly simplified and compact 5-cm-diameter clear aperture optics assembly is configured to single transmit and receive aperture laser signals. About 2 W of 4-channel multiplexed (1,540 to 1,555 nm) optically amplified laser power is coupled to the optical assembly through a fiber optic cable. It contains a highly compact, precision-pointing capability two-axis gimbal assembly to coarse point the optics assembly. A fast steering mirror, built into the optical path of the optical assembly, is used to remove residual pointing disturbances from the gimbal. Acquisition, pointing, and tracking are assisted by a beacon laser transmitted from the ground and received by the optical assembly, which will allow transmission of a laser beam.
3. Shifting the link burden to the ground by relying on direct detection optical receivers retrofitted to 1-m-diameter ground telescopes.
4. Favored mass and volume reduction over power-consumption reduction. The two major variables that are avail-
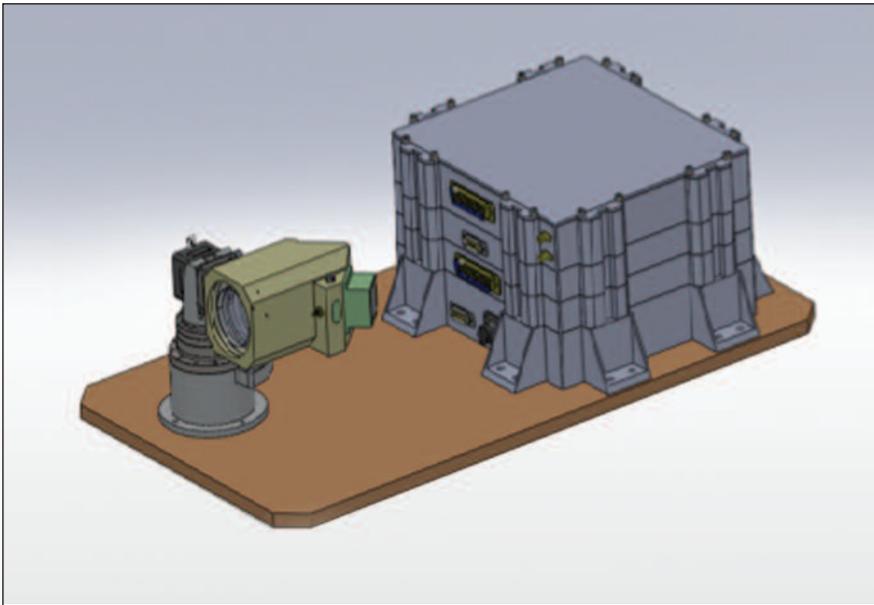
A **Laser Communications Terminal** consists of the optical head on a 2-axis gimbal (left), and an electronics/laser box (right).

able include laser transmit power at either end of the link, and telescope aperture diameter at each end of the link. Increased laser power is traded for smaller-aperture diameters.

5. Use of commercially available space-qualified or qualifiable components with traceability to flight qualification (i.e., a flight-qualified version is commercially available). An example is use of Telecordia-qualified fiber optic communication components including active components (lasers, amplifiers, photodetectors) that, ex-cept for vacuum and radiation, meet most of the qualifications required for space.

6. Use of CWDM technique at the flight transmitter for operation at four channels (each at 2.5 Gb/s or a total of 10 Gb/s data rate). Applying this technique allows utilization of larger active area photodetectors at the ground station. This minimizes atmospheric scintillation/turbulence in-duced losses on the received beam at the ground terminal.

7. Use of forward-error-correction and deep-interleaver codes to minimize atmospheric turbulence effects on the downlink beam.

Target mass and power consumption for the flight data transmitter system is less than 10 kg and approximately 60 W for the 400-km orbit (900-km slant range), and 12 kg and 120 W for the 2,000-km orbit (6,000-km slant range). The higher mass and power for the latter are the result of employing a higher-power laser only.

Application Program Interface for the Orion Aerodynamics Database

Lyndon B. Johnson Space Center, Houston, Texas

The Application Programming Interface (API) for the Crew Exploration Vehicle (CEV) Aerodynamic Database has been developed to provide the developers of software an easily implemented, fully self-contained method of accessing the CEV Aerodynamic Database for use in their analysis and simulation tools. The API is programmed in C and provides a series of functions to interact with the database, such as initialization, selecting various options, and calculating the aerodynamic data. No special functions (file read/write, table lookup) are required on the host system other than those included with a standard ANSI C installation. It reads one or more files of aero data tables.

Previous releases of aerodynamic databases for space vehicles have only included data tables and a document of the algorithm and equations to combine them for the total aerodynamic forces and moments. This process required each software tool to have a unique implementation of the database code. Errors or omissions in the documentation, or errors in the implementation, led to a lengthy and burden-some process of having to debug each instance of the code. Additionally, input file formats differ for each space vehicle simulation tool, requiring the aero database tables to be reformatted to meet the tool's input file structure requirements. Finally, the capabilities for built-in table lookup routines vary for each simulation tool. Implementation of a new database may require an update to and verification of the table lookup routines. This may be required if the number of dimensions of a data table exceeds the capability of the simulation tool's built-in lookup routines.

A single software solution was created to provide an aerodynamics software model that could be integrated into other simulation and analysis tools. The highly complex Orion aerodynamics model can then be quickly included in a wide variety of tools. The API code is written in ANSI C for ease of portability to a wide variety of systems. The input data files are in standard formatted ASCII, also for improved portability.

The API contains its own implementation of multidimensional table reading and lookup routines. The same aerodynamics input file can be used without modification on all implementations. The turnaround time from aerodynamics model release to a working implementation is significantly reduced.

Hyperspectral Imager-Tracker

John F. Kennedy Space Center, Florida

The Hyperspectral Imager-Tracker (HIT) is a technique for visualization and tracking of low-contrast, fast-moving objects. The HIT architecture is based on an innovative and only recently developed concept in imaging optics. This innovative architecture will give the Light Prescriptions Innovators (LPI) HIT the possibility of simultaneously collecting the spectral band images (hyperspectral cube), IR images, and to operate with high-light-gathering power and high magnification for multiple fast- moving objects. Adaptive Spectral Filtering algorithms will efficiently increase the contrast of low-contrast scenes.

The most hazardous parts of a space mission are the first stage of a launch and the last 10 kilometers of the landing trajectory.

In general, a close watch on spacecraft operation is required at distances up to 70 km. Tracking at such distances is usually associated with the use of radar, but its milliradian angular resolution translates to 100-m spatial resolution at 70-km distance. With sufficient power, radar can track a spacecraft as a whole object, but will not provide detail in the case of an accident, particularly for small debris in the one-meter range, which can only be achieved optically. It will be important to track the debris, which could disintegrate further into more debris, all the way to the ground. Such fragmentation could cause ballistic predictions, based on observations using high-resolution but narrow-field optics for only the first few seconds of the event, to be inaccurate. No optical imager architecture

exists to satisfy NASA requirements.

The HIT was developed for space vehicle tracking, in-flight inspection, and in the case of an accident, a detailed recording of the event. The system is a combination of five subsystems: (1) a "roving fovea" telescope with a wide 30° field of regard; (2) narrow, high-resolution "fovea" field optics; (3) a "Coude" optics system for telescope output beam stabilization; (4) a hyperspectral-mutispectral imaging assembly; and (5) image analysis software with effective adaptive spectral filtering algorithm for real-time contrast enhancement.

This work was done by Ilya Agurok of Prescriptions Innovators, LLC for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13234

Web Application Software for Ground Operations Planning Database (GOPDb) Management

John F. Kennedy Space Center, Florida

A Web application facilitates collaborative development of the ground operations planning document. This will reduce costs and development time for new programs by incorporating the data governance, access control, and revision tracking of the ground operations planning data.

Ground Operations Planning requires the creation and maintenance of detailed timelines and documentation. The GOPDb Web application was created using state-of-the-art Web 2.0 technologies, and was deployed as SaaS (Software as a Service), with an emphasis on data governance and security needs. Application access is managed using two-factor authentication, with data write permis-

sions tied to user roles and responsibilities. Multiple instances of the application can be deployed on a Web server to meet the robust needs for multiple, future programs with minimal additional cost.

This innovation features high availability and scalability, with no additional software that needs to be bought or installed. For data governance and security (data quality, management, business process management, and risk management for data handling), the software uses NAMS. No local copy/cloning of data is permitted. Data change log/tracking is addressed, as well as collaboration, work flow, and process standardization. The software provides on-

line documentation and detailed Web-based help.

There are multiple ways that this software can be deployed on a Web server to meet ground operations planning needs for future programs. The software could be used to support commercial crew ground operations planning, as well as commercial payload/satellite ground operations planning. The application source code and database schema are owned by NASA.

This work was done by Clifton Lanham of Kennedy Space Center, and Pravinkumar Asar, Shawn Kallner, and Jeffrey Gernand of SAIC. Further information is contained in a TSP (see page 1). KSC-13621

Electronics/Computers

Software Defined Radio With Parallelized Software Architecture

Goddard Space Flight Center, Greenbelt, Maryland

This software implements software-defined radio procession over multi-core, multi-CPU systems in a way that maximizes the use of CPU resources in the system. The software treats each processing step in either a communications or navigation modulator or demodulator system as an independent, threaded block. Each threaded block is defined with a programmable number of input or output buffers; these buffers are implemented using POSIX pipes. In addition, each threaded block is assigned a unique thread upon block installation. A modulator or demodulator system is built by assembly of the threaded blocks into a flow graph, which assembles the processing blocks to accomplish the desired signal processing. This software architecture allows the software to scale effortlessly between single CPU/single-core computers or multi-CPU/multi-core computers without recompilation.

NASA spaceflight and ground communications systems currently rely exclusively on ASICs or FPGAs. This software allows low- and medium-bandwidth (100 bps to ≈50 Mbps) software defined radios to be designed and implemented solely in C/C++ software, while lowering development costs and facilitating reuse and extensibility.

This work was done by Greg Heckler of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16442-1

Compact Radar Transceiver With Included Calibration
Volume and weight are reduced without performance penalties.

Goddard Space Flight Center, Greenbelt, Maryland

The Digital Beamforming Synthetic Aperture Radar (DBSAR) is an eight-channel phased array radar system that employs solid-state radar transceivers, a microstrip patch antenna, and a reconfigurable waveform generator and processor unit. The original DBSAR transceiver design utilizes connectorized electronic components that tend to be physically large and heavy. To achieve increased functionality in a smaller volume, PCB (printed circuit board) transceivers were designed to replace the large connectorized transceivers.

One of the most challenging problems designing the transceivers in a PCB format was achieving proper performance in the calibration path. For a radar loop-back calibration path, a portion of the transmit signal is coupled out of the antenna feed and fed back into the receiver. This is achieved using passive components for stability and repeatability. Some signal also leaks through the receive path. As these two signal paths are correlated via an unpredictable phase, the leakage through the receive path during transmit must be 30 dB below the calibration path. For DBSAR's design, this requirement called for a 100-dB isolation in the receiver path during transmit.

A total of 16 solid-state L-band transceivers on a PCB format were designed.

The transceivers include frequency conversion stages, T/R switching, and a calibration path capable of measuring the transmit power-receiver gain product during transmit for pulse-by-pulse calibration or matched filtering. In particular, this calibration path achieves 100-dB

isolation between the transmitted signal and the low-noise amplifier through the use of a switching network and a section of physical walls achieving attenuation of radiated leakage.

The transceivers were designed in microstrip PCBs with lumped elements and
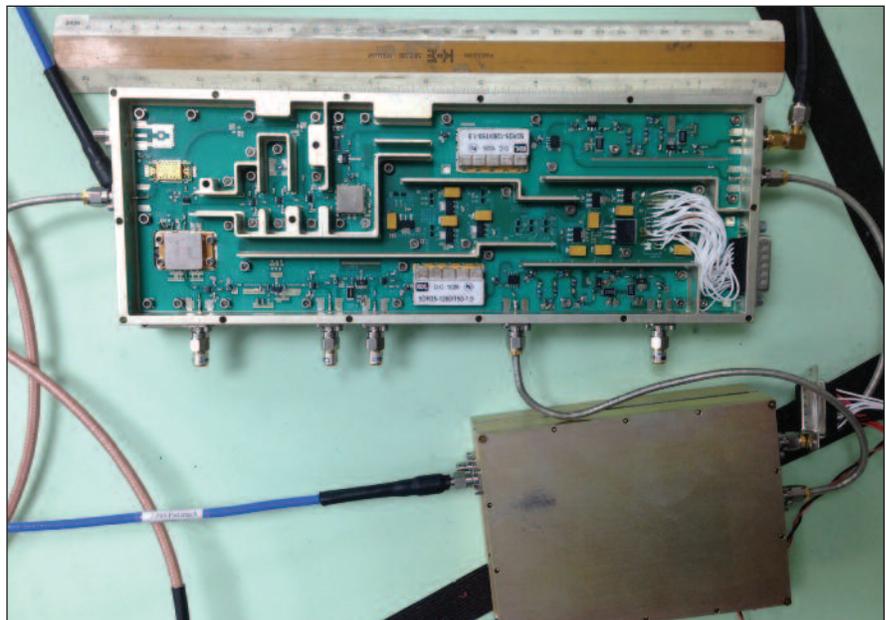
DBSAR's New Transceiver Architecture will enable the implementation and demonstration of the next-generation digital beamfoming synthetic aperture radar, and help advance the technology for infusion in future Earth science and planetary missions.

individually packaged components for compactness. Each transceiver was designed on a single PCB with a custom enclosure providing interior walls and compartments to isolate transceiver subsystems from radiated interference. The enclosure also acts as a heat sink for the voltage regulators and power amplifiers inside the system. The PCB transceiver design produces transmit pulses of 2 W with an arbitrary duty cycle. Each transceiver is fed by an external 120-MHz signal transmit and two 1,140-MHz local oscillator signals. The received signal is amplified and downconverted to 120 MHz and is fed to the data processor. The transceiver dimensions are approximately 3.5×11.5×0.6 in. (9×29×1.5 cm).

The PCB transceiver design reduces the volume and weight of the DBSAR instrument while maintaining the functionality found in the original design. Both volume and weight are critical for airborne and flight remote sensing instrumentation.

Software Defined Radio With Parallelized Software Architecture

Goddard Space Flight Center, Greenbelt, Maryland

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NASA spaceflight and ground communications systems currently rely exclusively on ASICs or FPGAs. This software allows low- and medium-bandwidth (100 bps to ≈50 Mbps) software defined radios to be designed and implemented solely in C/C++ software, while lowering development costs and facilitating reuse and extensibility.

Phase Change Material Thermal Power Generator

NASA's Jet Propulsion Laboratory, Pasadena, California

An innovative modification has been made to a previously patented design for the Phase Change Material (PCM) Thermal Generator, which works in water where ocean temperature alternatively melts wax in canisters, or allows the wax to re-solidify, causing high-pressure oil to flow through a hydraulic generator, thus creating electricity to charge a battery that powers the vehicle. In this modification, a similar thermal PCM device has been created that is heated and cooled by the air and solar radiation instead of using ocean temperature differences to change the PCM from solid to liquid. This innovation allows the device to use thermal energy to generate electricity on land, instead of just in the ocean.

This work was done by Jack A. Jones of Caltech for NASA's Kennedy Space Center. Further information is contained in a TSP (see page 1). NPO-48630

The Thermal Hogan — A Means of Surviving the Lunar Night

Lyndon B. Johnson Space Center, Houston, Texas

A document describes the Thermal Hogan, a new shelter concept that would be used on the Moon to moderate the extreme nighttime temperatures, allowing survival of equipment with minimal heater power. It is lightweight, has few mechanical parts, and would be relatively easy to deploy on the Moon.

The Lunar Hogan has two parts: an insulated shelter and a thermal mass. The shelter is constructed of multilayer insulation (MLI) draped over a structural framework. Entry and egress are accomplished either by raising the structure or via a door constructed of the same MLI material as the shelter. The thermal mass can be manufactured from locally available materials, either by piling substantially sized rocks to a depth of 0.25 meter, or by filling a 0.25-meter-deep conductive honeycomb-like structure with lunar dust. For ease of transport, the structural framework and honeycomb can be collapsible. The door can be opened by pushing on it in either direction. Gravity would cause it to close and it could be sealed via magnetic strips on the doorframe.

This work was done by Neelay Fruitwala, Eugene Ungar, and John Cornwell of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24898-1

Micromachined Active Magnetic Regenerator for Low-Temperature Magnetic Coolers

Fabrication improvements are evaluated and introduced.

Goddard Space Flight Center, Greenbelt, Maryland

A design of an Active Magnetic Regenerative Refrigeration (AMRR) system has been developed for space applications. It uses an innovative ^{3}He cryogenic circulator to provide continuous remote/distributed cooling at temperatures in the range of 2 K with a heat sink at about 15 K. A critical component technology for this cooling system is a highly efficient active magnetic regenerator, which is a regenerative heat exchanger with its matrix material made of magnetic refrigerant gadolinium gallium garnet (GGG).

Creare Inc. is developing a microchannel GGG regenerator with an anisotropic structured bed for high system thermal efficiency. The regenerator core consists of a stack of thin, single-crystal GGG disks alternating with thin polymer insulating layers. The insulating layers help minimize the axial conduction heat leak, since GGG has a very high thermal conductivity in the regenerator's operating temperature range. The GGG disks contain microchannels with width near 100 micrometers, which enhance the heat transfer between the circulating flow and the refrigerant bed. The unique flow configuration of the GGG plates ensures a uniform flow distribution across the plates.

The main fabrication challenges for the regenerator are the machining of
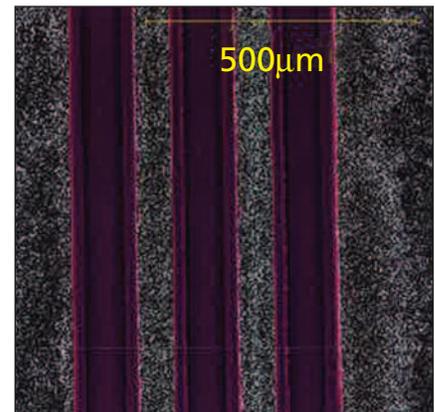
Microchannels in a 150-μm thick GGG disk fabricated by ultra-short pulse laser micromachining.

high-aspect-ratio microchannels in fragile, single-crystal GGG disks and fabrication and assembly of the GGG insulation layers. Feasibility demonstrations to date include use of an ultra-short-pulse laser to machine microchannels without producing unacceptable microcracking or deposition of recast material, as shown in the figure, and attachment of a thin insulation layer to a GGG disk without obstructing the flow paths. At the time of this reporting, efforts were focused on improving the laser machining process to increase machining speed and further reduce microcracking.

Materials & Coatings

Nano-Ceramic Coated Plastics
Adding this non-stick coating to cookware can create easy-to-clean plastic containers.

John H. Glenn Research Center, Cleveland, Ohio

Plastic products, due to their durability, safety, and low manufacturing cost, are now rapidly replacing cookware items traditionally made of glass and ceramics. Despite this trend, some still prefer relatively expensive and more fragile ceramic/glassware because plastics can deteriorate over time after exposure to foods, which can generate odors, bad appearance, and/or color change. Nano-ceramic coatings can eliminate these drawbacks while still retaining the advantages of the plastic, since the coating only alters the surface of the plastic. The surface coating adds functionality to the plastics such as self-cleaning and disinfectant capabilities that result from a photocatalytic effect of certain ceramic systems. These ceramic coatings can also provide non-stick surfaces and higher temperature capabilities for the base plastics without resorting to ceramic or glass materials.

Titanium dioxide (TiO_2) and zinc oxide (ZnO) are the candidates for a nano-ceramic coating to deposit on the plastics or plastic films used in cookware and kitchenware. Both are wide-bandgap semiconductors (3.0 to 3.2 eV for TiO_2 and 3.2 to 3.3 eV for ZnO), so they exhibit a photocatalytic property under ultraviolet (UV) light. This will lead to decomposition of organic compounds. Decomposed products can be easily washed off by water, so the use of detergents will be minimal. High-crystalline film with large surface area for the reaction is essential to guarantee good photocatalytic performance of these oxides. Low-temperature processing (<100 °C) is also a key to generating these ceramic coatings on the plastics.

One possible way of processing nano-ceramic coatings at low temperatures (< 90 °C) is to take advantage of *in-situ* precipitated nanoparticles and nanostructures grown from aqueous solution. These nanostructures can be tailored to ceramic film formation and the subsequent microstructure development. In addition, the process provides environment-friendly processing because of the aqueous solution. Low-temperature processing has also shown versatility to generate various nanostructures. The growth of low-dimensional nanostructures (0-D, 1-D) provides a means of enhancing the crystallinity of the solution-prepared films that is of importance for photocatalytic performance.

This technology can generate durable, fully functional nano-ceramic coatings (TiO_2, ZnO) on plastic materials (silicone, Teflon, PET, etc.) that can possess both photocatalytic oxide properties and flexible plastic properties. Processing cost is low and it does not require any expensive equipment investment. Processing can be scalable to current manufacturing infrastructure.

This work was done by Junghyun Cho of Binghamton University for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19005-1.

Preparation of a Bimetal Using Mechanical Alloying for Environmental or Industrial Use
This technology could be of use for catalyst production or environmental applications.

John F. Kennedy Space Center, Florida

Following the 1976 Toxic Substances Control Act ban on their manufacture, PCBs remain an environmental threat. PCBs are known to bio-accumulate and concentrate in fatty tissues. Further complications arise from the potential for contamination of commercial mixtures with other more toxic chlorinated compounds such as polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Until recently, only one option was available for the treatment of PCB-contaminated materials: incineration. This may prove to be more detrimental to the environment than the PCBs themselves due to the potential for formation of PCDDs.

Metals have been used for the past ten years for the remediation of halogenated solvents and other contaminants in the environment; however, zero-valent metals alone do not possess the activity required to dehalogenate PCBs. Palladium has been shown to act as an excellent catalyst for the dechlorination of PCBs with active metals. This invention is a method for the production of a palladium/magnesium bimetal capable of dechlorinating PCBs using mechanical milling/mechanical alloying. Other base metals and catalysts may also be alloyed together (e.g., nickel or zinc) to create a similarly functioning catalyst system. Several bimetal catalyst systems currently can be used for processes such as hydrogen peroxide synthesis, oxidation of ethane, selective oxidation, hydrogenation, and production of syngas for further conversion to clean fuels. The processes for making these bimetal catalysts often involve vapor deposition.

This technology provides an alternative to vapor deposition that may provide equally active catalysts.

A hydrogenation catalyst including a base material coated with a catalytic metal is made using mechanical milling techniques. The hydrogenation catalysts are used as an excellent catalyst for the dehalogenation of contaminated compounds and the remediation of other industrial compounds. The mechanical milling technique is simpler and cheaper than previously used methods for producing hydrogenation catalysts.

Preferably, the hydrogenation catalyst is a bimetallic particle formed from a zero-valent iron or zero-valent magnesium particle coated with palladium that is impregnated onto a high-surface-area graphite support. The zero-valent metal particles should be microscale or nanoscale zero-valent magnesium or zero-valent iron particles. Other zero-valent metal particles and combinations may be used. Additionally, the base material may be selected from a variety of minerals including, but not limited to, alumina and zeolites. The catalytic metal is preferably selected from the group consisting of noble metals and transition metals, preferably palladium.

The mechanical milling process includes milling the base material with a catalytic metal impregnated into a high-surface-area support to form the hydrogenation catalyst. In a preferred mechanical milling process, a zero-valent metal particle is provided as the base material, preferably having a particle size of less than about 10 microns, preferably 0.1 to 10 microns or smaller, prior to milling. The catalytic metal is supported on a conductive carbon support structure prior to milling. For example, palladium may be impregnated on a graphite support. Other support structures such as semiconductive metal oxides may also be used.

This work was done by Jacqueline Quinn of Kennedy Space Center and Cherie Geiger and Christian Clausen of the University of Central Florida. For more information, contact the KSC Technology Transfer Office at (321) 867-5033. KSC-12978

Phase Change Material for Temperature Control of Imager or Sounder on GOES Type Satellites in GEO

Goddard Space Flight Center, Greenbelt, Maryland

An imager or sounder on satellites, such as the Geostationary Operational Environmental Satellite (GOES), in geostationary orbit (GEO) has a scan mirror and motor in the scan cavity. The GEO orbit is 24 hours long. During part of the orbit, direct sunlight enters the scan aperture and adds heat to components in the scan cavity. Solar heating also increases the scan motor temperature. Overheating of the scan motor could reduce its reliability. For GOES-N to P, a radiator with a thermal louver rejects the solar heat absorbed to keep the scan cavity cool. A sunshield shields the radiator/louver from the Sun. This innovation uses phase change material (PCM) in the scan cavity to maintain the temperature stability of the scan mirror and motor.

When sunlight enters the scan aperture, solar heating causes the PCM to melt. When sunlight stops entering the scan aperture, the PCM releases the thermal energy stored to keep the components in the scan cavity warm. It reduces the heater power required to make up the heat lost by radiation to space through the aperture. This is a major advantage when compared to a radiator/louver. PCM is compact because it has a high solid-to-liquid enthalpy. Also, it could be spread out in the scan cavity. This is another advantage. Paraffin wax is a good PCM candidate, with high solid-to-liquid enthalpy, which is about 225 kJ/kg.

For GOES-N to P, a radiator with a louver rejects the solar heat that enters the aperture to keep the scan cavity cool. For the remainder of the orbit, sunlight does not enter the scan aperture. However, the radiator/louver continues radiating heat to space because the louver effective emittance is about 0.12, even if the louver is fully closed. This requires makeup heater power to maintain the temperature within the stability range.

This work was done by Michael Choi of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16546-1

Dual-Compartment Inflatable Suitlock

Lyndon B. Johnson Space Center, Houston, Texas

There is a need for an improvement over current NASA Extravehicular Activity (EVA) technology. The technology must allow the capacity for quicker, more efficient egress/ingress, allow for "shirtsleeve" suit maintenance, be compact in transport, and be applicable to environments ranging from planetary surface (partial-g) to orbital or deep space zero-g environments. The technology must also be resistant to dust and other foreign contaminants that may be present on or around a planetary surface. The technology should be portable, and be capable of docking with a variety of habitats, ports, stations, vehicles, and other pressurized modules.

The Dual-Compartment Inflatable Suitlock (DCIS) consists of three hard inline bulkheads, separating two cylindrical membrane-walled compartments. The Inner Bulkhead can be fitted with a variety of hatch types, docking flanges, and mating hardware, such as the Common Berthing Mechanism (CBM), for the purpose of mating with vehicles, habitats, and other pressurized modules. The Inner Bulkhead and Center Bulkhead function as the end walls of the Inner Compartment, which during operations, would stay pressurized, either matching the pressure of the habitat or acting as a lower-pressure transitional volume.

The Inner Compartment contains donning/doffing fixtures and inner suitport hatches. The Center Bulkhead has two integrated suitports along with a maintenance hatch. The Center Bulkhead and Outer Bulkhead function as the end walls of the Outer Compartment, which stays at vacuum during normal operations. This allows the crewmember to quickly don a suit, and egress the suitlock without waiting for the Outer Compartment to depressurize. The Outer Compartment can be pressurized infrequently for both nominal and off-nominal suit maintenance tasks, allowing shirtsleeve inspections and maintenance/repair of the environmental suits. The Outer Bulkhead has a pressure-assisted hatch door that stays open and stowed during EVA operations, but can be closed for environmental protection of the suits, suit maintenance, and pressurization.

This work was done by Kriss J. Kennedy, Peggy L. Guirgis, and Robert M. Boyle of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24914-1

Modular Connector Keying Concept

Lyndon B. Johnson Space Center, Houston, Texas

For panel-mount-type connectors, keying is usually "built-in" to the connector body, necessitating different part numbers for each key arrangement. This is costly for jobs that require small quantities. This invention was driven to provide a cost savings and to reduce documentation of individual parts.

The keys are removable and configurable in up to 16 combinations. Since the key parts are separate from the connector body, a common design can be used for the plug, receptacle, and key parts. The keying can then be set at the next higher assembly.

This work was done by Scott Ishman, Scott Dukes, and Gary Warnica of Honeywell, and Guy Conrad and Steven Senigla of Lockheed Martin for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-25074-1

Genesis Ultrapure Water Megasonic Wafer Spin Cleaner

Lyndon B. Johnson Space Center, Houston, Texas

A device removes, with high precision, the majority of surface particle contamination greater than 1-micron-diameter in size from ultrapure semiconductor wafer materials containing implanted solar wind samples returned by NASA's Genesis mission. This cleaning device uses a 1.5-liter/minute flowing stream of heated ultrapure water (UPW) with 1-MHz oscillating megasonic pulse energy focused at 3 to 5 mm away from the wafer surface spinning at 1,000 to 10,000 RPM, depending on sample size.

The surface particle contamination is removed by three processes: flowing UPW, megasonic cavitations, and centripetal force from the spinning wafer. The device can also dry the wafer fragment after UPW/megasonic cleaning by continuing to spin the wafer in the cleaning chamber, which is purged with flowing ultrapure nitrogen gas at 65 psi ($\approx$448 kPa). The cleaner also uses three types of vacuum chucks that can accommodate all Genesis-flown array fragments in any dimensional shape between 3 and 100 mm in diameter. A sample vacuum chuck, and the manufactured UPW/megasonic nozzle holder, replace the human deficiencies by maintaining a consistent dis-

tance between the nozzle and wafer surface as well as allowing for longer cleaning time. The 3- to 5-mm critical distance is important for the ability to remove particles by megasonic cavitations. The increased UPW sonication time and exposure to heated UPW improve the removal of 1- to 5-micron-sized particles.

This work was done by Judith H. Allton and Eileen K. Stansbery of Johnson Space Center, Michael J. Calaway of Jacobs Technology, and Melissa C. Rodriguez of Geocontrol Systems Inc. Further information is contained in a TSP (see page 1). MSC 24499-1

✿ Piezoelectrically Initiated Pyrotechnic Igniter

Lyndon B. Johnson Space Center, Houston, Texas

This innovation consists of a pyrotechnic initiator and piezoelectric initiation system. The device will be capable of being initiated mechanically; resisting initiation by EMF, RF, and EMI (electromagnetic field, radio frequency, and electromagnetic interference, respectively); and initiating in water environments and space environments.

Current devices of this nature are initiated by the mechanical action of a firing pin against a primer. Primers historically are prone to failure. These failures are commonly known as misfires or hang-fires. In many cases, the primer shows the dent where the firing pin struck the primer, but the primer failed to fire. In devices such as "T" handles, which are commonly used to initiate the blowout of canopies, loss of function of the device may result in loss of crew. In devices such as flares or smoke genera-

tors, failure can result in failure to spot a downed pilot.

The piezoelectrically initiated ignition system consists of a pyrotechnic device that plugs into a mechanical system (activator), which on activation, generates a high-voltage spark. The activator, when released, will strike a stack of electrically linked piezo crystals, generating a high-voltage, low-amperage current that is then conducted to the pyro-initiator. Within the initiator, an electrode releases a spark that passes through a pyrotechnic first-fire mixture, causing it to combust. The combustion of the first-fire initiates a primary pyrotechnic or explosive powder. If used in a "T" handle, the primary would ramp the speed of burn up to the speed of sound, generating a shock wave that would cause a high explosive to go "high order." In a flare or smoke generator, the secondary

would produce the heat necessary to ignite the pyrotechnic mixture.

The piezo activator subsystem is redundant in that a second stack of crystals would be struck at the same time with the same activation force, doubling the probability of a first strike spark generation. If the first activation fails to ignite, the device is capable of multiple attempts.

Another unique aspect is in the design of the pyrotechnic device. There is an electrode that aids the generation of a directed spark and the use of a conductive matrix to support the first-fire material so that the spark will penetrate to the second electrode.

This work was done by Asia Quince, Maureen Dutton, Robert Hicks, and Karen Burnham of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24841-1

✿ Folding Elastic Thermal Surface — FETS

By using tape-spring hinges, the FETS avoids the need for lubricants.

NASA's Jet Propulsion Laboratory, Pasadena, California

The FETS is a light and compact thermal surface (sun shade, IR thermal shield, cover, and/or deployable radiator) that is mounted on a set of offset tape-spring hinges. The thermal surface is constrained during launch and activated in space by a thermomechanical latch such as a wax actuator.

An application-specific embodiment of this technology developed for the MATMOS (Mars Atmospheric Trace Molecule Occultation Spectrometer) project serves as a deployable cover and thermal shield for its passive cooler. The FETS fits compactly against the instrument within the constrained launch envelope, and then unfolds into a larger area once in space. In this application, the FETS protects the passive cooler from thermal damage and contamination during ground operations, launch,
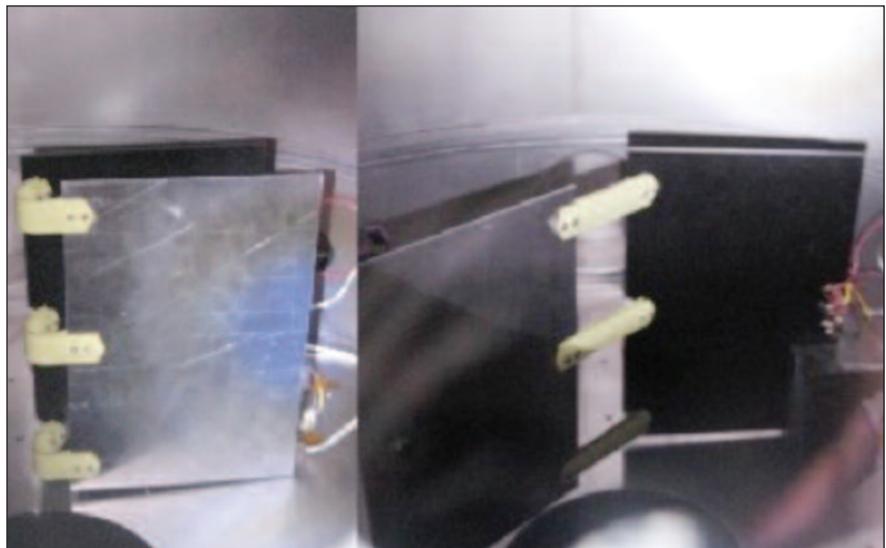
The figure depicts the **FETS** in its stowed and deployed states during high vacuum testing at JPL.

and during orbit insertion. Once unfolded or deployed, the FETS serves as a heat shield, intercepting parasitic heat loads by blocking the passive cooler's view of the warm spacecraft.

The technology significantly enhances the capabilities of instruments requiring either active or passive cooling of optical detectors. This can be particularly important for instruments where performance is limited by the available radiator area. Examples would be IR optical instruments on CubeSATs or those launched as hosted payloads because radiator area is limited and views are often undesirable. As a deployable radiator, the panels making up the FETS are linked thermally by thermal straps and heat pipes; the structural support and deployment energy is provided using tape-spring hinges.

The FETS is a novel combination of existing technologies. Prior art for deployable heat shields uses rotating hinges that typically must be lubricated to avoid cold welding or static friction. By using tape-spring hinges, the FETS avoids the need for lubricants by avoiding friction altogether. This also eliminates the potential for contamination of nearby cooled optics by outgassing lubricants. Furthermore, the tape-spring design of the FETS is also self-locking so the panels stay in a rigid and extended configuration after deployment. This unexpected benefit makes the tape-spring hinge design of the FETS a light, simple, reliable, compact, non-outgassing hinge, spring, and latch.

While tape-spring hinges are not novel, they have never been used to deploy passive unfolding thermal surfaces (radiator panels, covers, sun shades, or IR thermal shields). Furthermore, because this technology is compact, it has minimal impact on the launch envelope and mass specifications. FETS enhances the performance of hosted payload instruments where the science data is limited by dark noise.

Incorporating FETS into a thermal control system increases radiator area, which lowers the optical detector temperature. This results in higher SNR (signal-to-noise ratio) and improved science data.

Multi-Pass Quadrupole Mass Analyzer

The technology will enhance the resolving power of small QMA instruments and simplify the electronics package for ground and space instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

Analysis of the composition of planetary atmospheres is one of the most important and fundamental measurements in planetary robotic exploration. Quadrupole mass analyzers (QMAs) are the primary tool used to execute these investigations, but reductions in size of these instruments has sacrificed mass resolving power so that the best present-day QMA devices are still large, expensive, and do not deliver performance of laboratory instruments.

An ultra-high-resolution QMA was developed to resolve N_2^+/CO^+ by trapping ions in a linear trap quadrupole filter. Because N_2 and CO are resolved, gas chromatography columns used to separate species before analysis are eliminated, greatly simplifying gas analysis instrumentation. For highest performance, the ion trap mode is used. High-resolution (or narrow-band) mass selection is carried out in the central region, but near the DC electrodes at each end, RF/DC field settings are adjusted to allow broadband ion passage. This is to prevent ion loss during ion "reflection" at each end. Ions are created inside the trap so that low-energy particles are selected by low-voltage settings on the end electrodes. This is beneficial to good mass resolution since low-energy particles traverse many cycles of the RF filter-

ing fields. Through Monte Carlo simulations, it is shown that ions are reflected at each end many tens of times, each time being sent back through the central section of the quadrupole where ultrahigh mass filtering is carried out. An analyzer was produced with electrical length orders of magnitude longer than its physical length. Since the selector fields are sized as in conventional devices, the loss of sensitivity inherent in miniaturizing quadrupole instruments is avoided. The no-loss, multi-pass QMA architecture will improve mass resolution of planetary QMA instruments while reducing demands on the RF electronics for high-voltage/high-frequency production since ion transit time is no longer limited to a single pass. The QMA-based instrument will thus give way to substantial reductions of the mass of flight instruments. Advantages of the multi-pass quadrupole mass analyzer include:
- Provides ultra-high-resolution mass analysis to resolve N_2^+/CO^+ and Ne^+/Ar^{++}.
- Multiple passes through QMA region.
- Very slow ions can be created inside the trap compared to beam injection into conventional QMA.
- Low-risk, high-resolution performance sufficient to resolve N_2^+/CO^+ has already been demonstrated. This work will improve signal efficiency by 100-fold.

- Discovery, MIDEX, and all planetary science will advance by use of multi-pass QMA instrument development.
- Eliminates trade-off between high-voltage and high-frequency RF mass selector fields.
- Both high mass operation and high resolution are achievable in the multi-pass QMA.
- Mass range to over 1,000 Daltons will be provided.
- Recycling ion passage through mass selector fields, filtering length is orders of magnitude longer than physical length, matching resolution of the best ground-based instruments.
- This technique can be applied to improve mass resolution of ultra-miniature QMA devices.
- This approach reduces the risk and loss of resolution typically encountered in miniaturization of a quadrupole gas analyzer since the QMA device uses conventional-sized quadrupole filtering fields, acceptance angles, etc. as currently used in planetary instruments.

The pre-analysis provided by gas chromatography columns will not be required.

This work was done by John D. Prestage of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47277

Lunar Sulfur Capture System

The process substantially reduces the need for Earth-supplied consumables.

John F. Kennedy Space Center, Florida

The Lunar Sulfur Capture System (LSCS) protects in situ resource utilization (ISRU) hardware from corrosion, and reduces contaminant levels in water condensed for electrolysis. The LSCS uses a lunar soil sorbent to trap over 98 percent of sulfur gases and about two-thirds of halide gases evolved during hydrogen reduction of lunar soils. LSCS soil sorbent is based on lunar minerals

containing iron and calcium compounds that trap sulfur and halide gas contaminants in a fixed-bed reactor held at temperatures between 250 and 400 °C, allowing moisture produced during reduction to pass through in vapor phase. Small amounts of Earth-based polishing sorbents consisting of zinc oxide and sodium aluminate are used to reduce contaminant concentrations to

one ppm or less. The preferred LSCS configuration employs lunar soil beneficiation to boost concentrations of reactive sorbent minerals.

Lunar soils contain sulfur in concentrations of about 0.1 percent, and halogen compounds including chlorine and fluorine in concentrations of about 0.01 percent. These contaminants are released as gases such as H_2S, COS, CS_2,

HCl, and HF during thermal ISRU processing with hydrogen or other reducing gases. Removal of contaminant gases is required during ISRU processing to prevent hardware corrosion, electrolyzer damage, and catalyst poisoning. The use of Earth-supplied, single-use consumables to entirely remove contaminants at the levels existing in lunar soils would make many ISRU processes unattractive due to the large mass of consumables relative to the mass of oxygen produced. The LSCS concept of using a primary sorbent prepared from lunar soil was identified as a method by which the ma-

jority of contaminants could be removed from process gas streams, thereby substantially reducing the required mass of Earth-supplied consumables.

The LSCS takes advantage of minerals containing iron and calcium compounds that are present in lunar soil to trap sulfur and halide gases in a fixed-bed reactor downstream of an in-ISRU process such as hydrogen reduction. The lunar-soil-sorbent trap is held at a temperature significantly lower than the operating temperature of the hydrogen reduction or other ISRU process in order to maximize capture of

contaminants, but is held at a high enough temperature to allow moisture to pass through without condensing. The lunar soil benefits from physical beneficiation to remove ultrafine particles (to reduce pressure drop through a fixed bed reactor) and to upgrade concentrations of iron and/or calcium compounds (to improve reactivity with gaseous contaminants).

Environmental Qualification of a Single-Crystal Silicon Mirror for Spaceflight Use

Goddard Space Flight Center, Greenbelt, Maryland

This innovation is the environmental qualification of a single-crystal silicon mirror for spaceflight use. The single-crystal silicon mirror technology is a previous innovation, but until now, a mirror of this type has not been qualified for spaceflight use. The qualification steps included mounting, gravity change measurements, vibration testing, vibration-induced change measurements, thermal cycling, and testing at the cold operational temperature of 225 K.

Typical mirrors used for cold applications for spaceflight instruments include aluminum, beryllium, glasses, and glass-like ceramics. These materials show less than ideal behavior after cooldown. Single-crystal silicon has been demonstrated to have the smallest change due to temperature change, but has not been spaceflight-qualified for use. The advantage of using a silicon substrate is with temperature stability, since it is formed from a stress-free sin-

gle crystal. This has been shown in previous testing. Mounting and environmental qualification have not been shown until this testing.

Planar Superconducting Millimeter-Wave/Terahertz Channelizing Filter

The design enables multiple-octave operation with no spurious harmonic response.

Goddard Space Flight Center, Greenbelt, Maryland

This innovation is a compact, superconducting, channelizing bandpass filter on a single-crystal (0.45 µm thick) silicon substrate, which operates from 300 to 600 GHz. This device consists of four channels with center frequencies of 310, 380, 460, and 550 GHz, with approximately 50-GHz bandwidth per channel. The filter concept is inspired by the mammalian cochlea, which is a channelizing filter that covers three decades of bandwidth and 3,000 channels in a very small physical space. By using a simplified physical cochlear model, and its electrical analog of a channelizing filter covering multiple octaves bandwidth, a large number of out-

put channels with high inter-channel isolation and high-order upper stopband response can be designed.

A channelizing filter is a critical component used in spectrometer instruments that measure the intensity of light at various frequencies. This embodiment was designed for MicroSpec in order to increase the resolution of the instrument (with four channels, the resolution will be increased by a factor of four). MicroSpec is a revolutionary wafer-scale spectrometer that is intended for the SPICA (Space Infrared Telescope for Cosmology and Astrophysics) Mission. In addition to being a vital component of MicroSpec, the chan-

nelizing filter itself is a low-resolution spectrometer when integrated with only an antenna at its input, and a detector at each channel's output.

During the design process for this filter, the available characteristic impedances, possible lumped element ranges, and fabrication tolerances were identified for design on a very thin silicon substrate. Iterations between full-wave and lumped-element circuit simulations were performed. Each channel's circuit was designed based on the availability of characteristic impedances and lumped element ranges.

This design was based on a tabular type bandpass filter with no spurious har-

monic response. Extensive electromagnetic modeling for each channel was performed. Four channels, with 50-GHz bandwidth, were designed, each using multiple transmission line media such as microstrip, coplanar waveguide, and quasi-lumped components on 0.45-μm thick silicon. In the design process, modeling issues had to be overcome. Due to the extremely high frequencies, very thin Si substrate, and the superconducting metal layers, most commercially available software fails in various ways. These issues were mitigated by using alternative software that was capable of handling them at the expense of greater simulation time. The design of on-chip components for the filter characterization, such as a broadband antenna, Wilkinson power dividers, attenuators, detectors, and transitions has been completed.

This work was done by Negar Ehsan, Kongpop U-yen, Ari Brown, Wen-Ting Hsieh, Edward Wollack, and Samuel Moseley of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).
GSC-16486-1

Qualification of UHF Antenna for Extreme Martian Thermal Environments

## This innovation can be used in aerospace and deep space applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

The purpose of this development was to validate the use of the external Rover Ultra High Frequency (RUHF) antenna for space under extreme thermal environments to be encountered during the surface operations of the Mars Science Laboratory (MSL) mission. The antenna must survive all ground operations plus the nominal 670 Martian sol mission that includes summer and winter seasons of the Mars thermal environment. The qualification effort was to verify that the RUHF antenna design and its bonding and packaging processes are adequate to survive the harsh environmental conditions.

The RUHF is a quadrifilar helix antenna mounted on the MSL Curiosity rover deck. The main components of the RUHF antenna are the helix structure, feed cables, and hybrid coupler, and the high-power termination load.

In the case of MSL rover externally mounted hardware, not only are the expected thermal cycle depths severe, but there are temperature offsets between the Mars summer and winter seasons. The total number of temperature cycles needed to be split into two regimes of summer cycles and winter cycles.

The qualification test was designed to demonstrate a survival life of three times more than all expected ground testing, plus a nominal 670 Martian sol missions. Baseline RF tests and a visual inspection were performed prior to the start of the qualification test. Functional RF tests were performed intermittently during chamber breaks over the course of the qualification test. For the RF return loss measurements, the antenna was tested in a controlled environment outside the thermal chamber with a vector network analyzer that was calibrated over the antenna's operational frequency range.
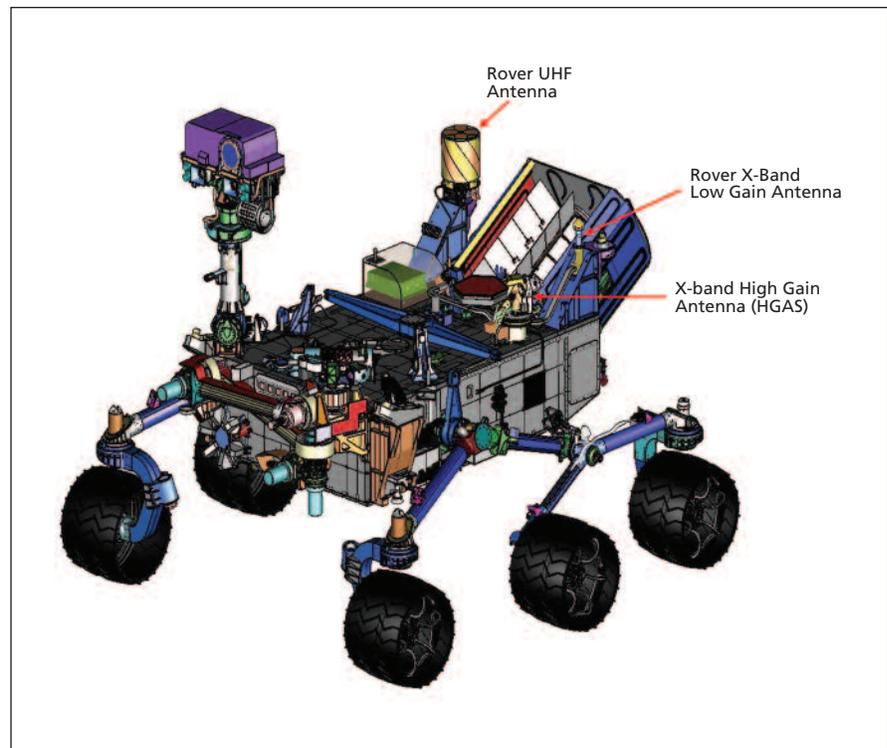
The locations of the **Rover UHF (RUHF)**, rover X-band low-gain, and rover X-band high-gain antennas on the Mars Science Laboratory rover.

A total of 2,010 thermal cycles were performed. Visual inspection showed a dulling of the solder material. This change will not affect the performance of the antenna. No other changes were observed. RF tests were performed on the RUHF helix antenna, hybrid, and load after the 2,010 qualification cycles test. The RF performance of the RUHF antenna, hybrid, and load were almost identical before and after the complete test. Therefore, the developed design of RUHF is qualified for a long-duration MSL mission.

The RUHF antenna has not been used for long-duration missions such as MSL in the past. The state-of-the-art technology of the RUHF antenna is used to develop the antennas for MSL mission survivability. This developmental test data provides the confidence in using this RUHF antenna for future NASA missions to Mars.

This work was done by Rajeshuni Ramesham, Luis R. Amaro, Paula R. Brown, and Robert Usiskin of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-48475

Software

▶ Ensemble Eclipse: A Process for Prefab Development Environment for the Ensemble Project

This software simplifies the process of having to set up an Eclipse IDE programming environment for the members of the cross-NASA center project, Ensemble. It achieves this by assembling all the necessary add-ons and custom tools/preferences.

This software is unique in that it allows developers in the Ensemble Project (approximately 20 to 40 at any time) across multiple NASA centers to set up a development environment almost instantly and work on Ensemble software. The software automatically has the source code repositories and other vital information and settings included.

The Eclipse IDE is an open-source development framework. The NASA (Ensemble-specific) version of the software includes Ensemble-specific plug-ins as well as settings for the Ensemble project. This software saves developers the time and hassle of setting up a programming environment, making sure that everything is set up in the correct manner for Ensemble development.

Existing software (i.e., standard Eclipse) requires an intensive setup process that is both time-consuming and error prone. This software is built once by a single user and tested, allowing other developers to simply download and use the software.

This work was done by Michael N. Wallick, David S. Mittman, and Khawaja S. Shams of Caltech; and Andrew G. Bachmann and Melissa Ludowise of NASA Ames Research Center for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47677.

▶ ISS Live!

International Space Station Live! (ISSLive!) is a Web application that uses a proprietary commercial technology called Lightstreamer to push data across the Internet using the standard http port (port 80). ISSLive! uses the push technology to display real-time telemetry and mission timeline data from the space station in any common Web browser or Internet-enabled mobile device.

ISSLive! is designed to fill a unique niche in the education and outreach areas by providing access to real-time space station data without a physical presence in the mission control center. The technology conforms to Internet standards, supports the throughput needed for real-time space station data, and is flexible enough to work on a large number of Internet-enabled devices.

ISSLive! consists of two custom components: (1) a series of data adapters that resides server-side in the mission control center at Johnson Space Center, and (2) a set of public html that renders the data pushed from the data adapters. A third component, the Lightstreamer server, is commercially available from a third party and acts as an intermediary between custom components (1) and (2). Lightstreamer also provides proprietary software libraries that are required to use the custom components.

At the time of this reporting, this is the first usage of Web-based, push streaming technology in the aerospace industry.

This work was done by Jennifer Price and Philip Harris of Johnson Space Center; Bruce Hochstetler, Mark Guerra, and Israel Mendez of Tietronix Software, Inc.; and Matthew Healy and Ahmed Khan of the United Space Alliance. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-25253-1

▶ Space Operations Learning Center (SOLC) iPhone/iPad Application

This iPhone application, Space Junk Sammy, is intended to be an educational application designed for Apple iPhones and iPads. This new concept educates kids in an innovative way about how orbital debris affects space missions.

Orbital debris is becoming a very significant concern for NASA and all Earth-orbiting space missions. Spacecraft in low-Earth orbit are in constant danger of being potentially damaged or destroyed by debris. High-profile spacecraft such as the International Space Station (ISS) and Hubble Space Telescope are dealing with orbital debris on a regular basis. Other basic educational concepts that are portrayed are low-Earth orbits, satel-

lites, ISS, attitude control, and other facts that can be presented in between-level popup screens.

The Orbital Debris Cleanup game is relatively simple from the user's technical standpoint. It is a 2D game where the user's avatar is a satellite buddy, named Sammy, in orbit around Earth. Sammy is controlled by the user with the device's gyroscope as well as touchscreen controls. It has equipment used for taking care of the space debris objects on the screen. Sammy also has a claw, a laser deflector, and hydrazine rockets to grab or push the debris objects into a higher orbit or into a lower orbit to burn up in the Earth's atmosphere.

The user interface shows Sammy and space debris objects constantly moving from left to right, where Sammy is trying to "catch" the debris objects before they move off the right side of the screen. Everything will be in constant motion to increase fun and add to the realism of orbiting the Earth. The satellite buddy is used to clean up the space debris and protect other satellites. Later levels will include a laser deflector and hydrazine rockets instead of a robotic claw to push the orbital debris into a higher orbit and out of the path of other satellites.

This work was done by Daniel Binebrink, Heng Kuok, Malinda Hammond, and Scott Hull of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16612-1

▶ Software to Compare NPP HDF5 Data Files

This software was developed for the NPOESS (National Polar-orbiting Operational Environmental Satellite System) Preparatory Project (NPP) Science Data Segment. The purpose of this software is to compare HDF5 (Hierarchical Data Format) files specific to NPP and report whether the HDF5 files are identical. If the HDF5 files are different, users have the option of printing out the list of differences in the HDF5 data files.

The user provides paths to two directories containing a list of HDF5 files to compare. The tool would select matching HDF5 file names from the two directories and run the comparison on each file.

The user can also select from three levels of detail. Level 0 is the basic level, which simply states whether the files

match or not. Level 1 is the intermediate level, which lists the differences between the files. Level 2 lists all the details regarding the comparison, such as which objects were compared, and how and where they are different.

The HDF5 tool is written specifically for the NPP project. As such, it ignores certain attributes (such as creation_date, creation_time, etc.) in the HDF5 files. This is because even though two HDF5 files could represent exactly the same granule, if they are created at different times, the creation date and time would be different. This tool is smart enough to ignore differences that are not relevant to NPP users.

Information Technology

❯ Planetary Data Systems (PDS) Imaging Node Atlas II

NASA's Jet Propulsion Laboratory, Pasadena, California

The Planetary Image Atlas (PIA) is a Rich Internet Application (RIA) that serves planetary imaging data to the science community and the general public. PIA also utilizes the USGS Unified Planetary Coordinate system (UPC) and the on-Mars map server.

The Atlas was designed to provide the ability to search and filter through greater than 8 million planetary image files. This software is a three-tier Web application that contains a search engine backend (MySQL, JAVA), Web service interface (SOAP) between server and client, and a GWT Google Maps API client front end. This application allows for the search, retrieval, and download of planetary images and associated meta-data from the following missions:

2001 Mars Odyssey, Cassini, Galileo, LCROSS, Lunar Reconnaissance Orbiter, Mars Exploration Rover, Mars Express, Magellan, Mars Global Surveyor, Mars Pathfinder, Mars Reconnaissance Orbiter, MESSENGER, Phoenix, Viking Lander, Viking Orbiter, and Voyager.

The Atlas utilizes the UPC to translate mission-specific coordinate systems into a unified coordinate system, allowing the end user to query across missions of similar targets. If desired, the end user can also use a mission-specific view of the Atlas. The mission-specific views rely on the same code base.

This application is a major improvement over the initial version of the Planetary Image Atlas. It is a multi-mission search engine. This tool includes both basic and advanced search capabilities, providing a product search tool to interrogate the collection of planetary images. This tool lets the end user query information about each image, and ignores the data that the user has no interest in. Users can reduce the number of images to look at by defining an area of interest with latitude and longitude ranges.

This work was done by Alice Stanboli and James M. McAuley of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47820.

❯ Automatic Calibration of an Airborne Imaging System to an Inertial Navigation Unit

NASA's Jet Propulsion Laboratory, Pasadena, California

This software automatically calibrates a camera or an imaging array to an inertial navigation system (INS) that is rigidly mounted to the array or imager. In effect, it recovers the coordinate frame transformation between the reference frame of the imager and the reference frame of the INS.

This innovation can automatically derive the camera-to-INS alignment using image data only. The assumption is that the camera fixates on an area while the aircraft flies on orbit. The system then, fully automatically, solves for the camera orientation in the INS frame. No manual intervention or ground tie point data is required.

This work was done by Adnan I. Ansar, Daniel S. Clouse, Michael C. McHenry, Dimitri V. Zarzhitsky, and Curtis W. Padgett of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48755.

❯ Translating MAPGEN to ASPEN for MER

Faithful translation is achieved from mixed-domain representations into the ASPEN Modeling Language.

NASA's Jet Propulsion Laboratory, Pasadena, California

This software translates MAPGEN (Europa and APGEN) domains to ASPEN, and the resulting domain can be used to perform planning for the Mars Exploration Rover (MER). In other words, this is a conversion of two distinct planning languages (both declarative and procedural) to a third (declarative) planning language in order to solve the problem of faithful translation from mixed-domain representations into the ASPEN Modeling Language.

The MAPGEN planning system is an example of a hybrid procedural/declarative system where the advantages of each are leveraged to produce an effective planner/scheduler for MER tactical planning. The adaptation of the

same domain to an entirely declarative planning system (ASPEN) was investigated, and, with some translation, much of the procedural knowledge encoding is amenable to declarative knowledge encoding.

The approach was to compose translators from the core languages used for adapting MAGPEN, which consists of Europa and APGEN. Europa is a constraint-based planner/scheduler where domains are encoded using a declarative model. APGEN is also constraint-based, in that it tracks constraints on resources and states and other variables. Domains are encoded in both constraints and code snippets that execute according to a forward sweep through the plan. Europa and APGEN communicate to each other using proxy activities in APGEN that represent constraints and/or tokens in Europa. The composition of a translator from Europa to ASPEN was fairly straightforward, as ASPEN is also a declarative planning system, and the specific uses of Europa for the MER domain matched ASPEN's native encoding fairly closely.

On the other hand, translating from APGEN to ASPEN was considerably more involved. On the surface, the types of activities and resources one encodes in APGEN appear to match one-to-one to the activities, state variables, and resources in ASPEN. But, when looking into the definitions of how resources are profiled and activities are expanded, one sees code snippets that access various information available during planning for the moment in time being planned to decide at the time what the appropriate profile or expansion is. APGEN is actually a forward (in time) sweeping discrete event simulator, where the model is composed of code snippets that are artfully interleaved by the engine to produce a plan/schedule. To solve this problem, representative code is simulated as a declarative series of task expansions.

Predominantly, three types of procedural models were translated: loops, if-statements, and code blocks. Loops and if-statements were handled using controlled task expansion, and code blocks were handled using constraint networks that maintained the generation of results based on what the order of execution would be for a procedural representation.

One advantage with respect to performance for MAPGEN is the use of APGEN's GUI. This GUI is written in C++ and Motif, and performs very well for large plans.

Support Routines for In Situ Image Processing

NASA's Jet Propulsion Laboratory, Pasadena, California

This software consists of a set of application programs that support ground-based image processing for *in situ* missions. These programs represent a collection of utility routines that perform miscellaneous functions in the context of the ground data system. Each one fulfills some specific need as determined via operational experience. The most unique aspect to these programs is that they are integrated into the large, *in situ* image processing system via the PIG (Planetary Image Geometry) library. They work directly with space *in situ* data, understanding the appropriate image meta-data fields and updating them properly. The programs themselves are completely multimission; all mission dependencies are handled by PIG.

This suite of programs consists of:

- marscahv: Generates a linearized, epipolar aligned image given a stereo pair of images. These images are optimized for 1-D stereo correlations.
- marscheckcm: Compares the camera model in an image label with one derived via kinematics modeling on the ground.
- marschkovl: Checks the overlaps between a list of images in order to determine which might be stereo pairs. This is useful for non-traditional stereo images like long-baseline or those from an articulating arm camera.
- marscoordtrans: Translates mosaic coordinates from one form into another.
- marsdispcompare: Checks a Left→Right stereo disparity image against a Right→Left disparity image to ensure they are consistent with each other.
- marsdispwarp: Takes one image of a stereo pair and warps it through a disparity map to create a synthetic opposite-eye image. For example, a right eye image could be transformed to look like it was taken from the left eye via this program.
- marsfidfinder: Finds fiducial markers in an image by projecting their approximate location and then using correlation to locate the markers to subpixel accuracy. These fiducial markets are small targets attached to the spacecraft surface. This helps verify, or improve, the pointing of *in situ* cameras.
- marsinvrange: Inverse of marsrange — given a range file, re-computes an XYZ file that closely matches the original.
- marsproj: Projects an XYZ coordinate through the camera model, and reports the line/sample coordinates of the point in the image.
- marsprojfid: Given the output of marsfidfinder, projects the XYZ loca-tions and compares them to the found locations, creating a report showing the fiducial errors in each image.
- marsrad: Radiometrically corrects an image.
- marsrelabel: Updates coordinate system or camera model labels in an image.
- marstiexyz: Given a stereo pair, allows the user to interactively pick a point in each image and reports the XYZ value corresponding to that pair of locations.
- marsunmosaic: Extracts a single frame from a mosaic, which will be created such that it could have been an input to the original mosaic. Useful for creating simulated input frames using different camera models than the original mosaic used.
- merinverter: Uses an inverse lookup table to convert 8-bit telemetered data to its 12-bit original form. Can be used in other missions despite the name.

Semi-Supervised Eigenbasis Novelty Detection

NASA's Jet Propulsion Laboratory, Pasadena, California

Recent discoveries in high-time-resolution radio astronomy data have focused attention on a new class of events. Fast transients are rare pulses of radio frequency energy lasting from microseconds to seconds that might be produced by a variety of exotic astrophysical phenomena. For example, X-ray bursts, neutron stars, and active galactic nuclei are all possible sources of short-duration, transient radio signals. It is difficult to anticipate where such signals might appear, and they are most commonly discovered through analysis of high-time-resolution data that had been collected for other purposes. Transients are often faint and difficult to detect, so improved detection algorithms can directly benefit the science yield of all such commensal monitoring.

A new detection algorithm learns a low-dimensional linear manifold for describing the "normal" data. High reconstruction error indicates a novel signal that does not match the patterns of normal data. One unsupervised portion of the manifold model adapts its representation in response to recent data. A second supervised portion of the model is made of a basis trained in advance using labeled examples of RFI; this prevents false positives due to these events. For a linear model, an orthonormalization operation is used to combine these bases prior to the anomaly detection decision.

Another novel aspect of the approach lies in combining basis vectors learned in an unsupervised, online fashion from the data stream with supervised basis vectors learned in advance from known examples of false alarms. Adaptive, data-driven detection is achieved that is also informed by existing domain knowledge about signals that may be statistically anomalous, but are not interesting and should therefore be ignored.

The method was evaluated using data from the Parkes Multibeam Survey. This data set was originally collected to search for pulsars, which are astronomical sources that emit radio pulses at regular periods. However, several non-pulsar anomalies have recently been discovered in this dataset, making it a compelling test case. By explicitly filtering known false alarm patterns, the approach yields significantly better performance than current transient detection methods.

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Space Administration