



# 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

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## NASA Field Centers and Program Offices

Ames Research Center  
Mary Walsh  
(650) 604-1405  
[mary.w.walsh@nasa.gov](mailto:mary.w.walsh@nasa.gov)

Dryden Flight Research Center  
Ron Young  
(661) 276-3741  
[ronald.m.young@nasa.gov](mailto:ronald.m.young@nasa.gov)

Glenn Research Center  
Joe Shaw  
(216) 977-7135  
[robert.j.shaw@nasa.gov](mailto:robert.j.shaw@nasa.gov)

Goddard Space Flight Center  
Nona Cheeks  
(301) 286-5810  
[nona.k.cheeks@nasa.gov](mailto:nona.k.cheeks@nasa.gov)

Jet Propulsion Laboratory  
Indrani Graczyk  
(818) 354-2241  
[indrani.graczyk@jpl.nasa.gov](mailto:indrani.graczyk@jpl.nasa.gov)

Johnson Space Center  
John E. James  
(281) 483-3809  
[john.e.james@nasa.gov](mailto:john.e.james@nasa.gov)

Kennedy Space Center  
David R. Makufka  
(321) 867-6227  
[david.r.makufka@nasa.gov](mailto:david.r.makufka@nasa.gov)

Langley Research Center  
Michelle Ferebee  
(757) 864-5617  
[michelle.t.ferebee@nasa.gov](mailto:michelle.t.ferebee@nasa.gov)

Marshall Space Flight Center  
Jim Dowdy  
(256) 544-7604  
[jim.dowdy@nasa.gov](mailto:jim.dowdy@nasa.gov)

Stennis Space Center  
Ramona Travis  
(228) 688-3832  
[ramona.e.travis@ssc.nasa.gov](mailto:ramona.e.travis@ssc.nasa.gov)

### NASA Headquarters

Innovative Partnerships Office  
Doug Comstock, Director  
(202) 358-2221  
[doug.comstock@nasa.gov](mailto:doug.comstock@nasa.gov)

Daniel Lockney,  
Technology Transfer Lead  
(202) 358-2037  
[daniel.p.lockney@nasa.gov](mailto:daniel.p.lockney@nasa.gov)

Small Business Innovation Research  
(SBIR) & Small Business Technology  
Transfer (STTR) Programs  
Carl Ray, Program Executive  
(202) 358-4652  
[carl.g.ray@nasa.gov](mailto:carl.g.ray@nasa.gov)





# TECH BRIEFS

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## Spectral Profiler Probe for *In Situ* Snow Grain Size and Composition Stratigraphy

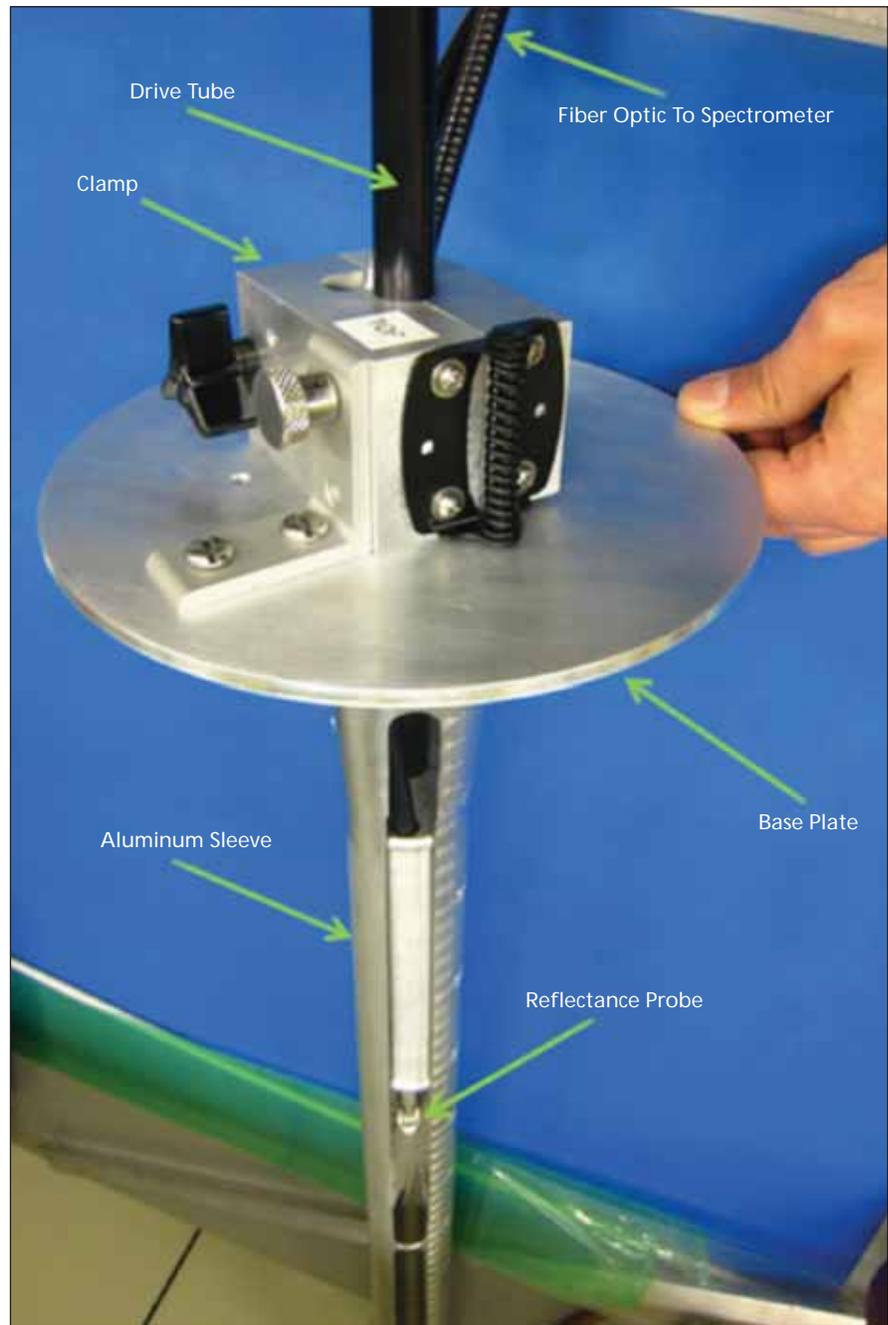
This device can be used by water resource personnel to obtain snowpack data.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An ultimate goal of the climate change, snow science, and hydrology communities is to measure snow water equivalent (SWE) from satellite measurements. Seasonal SWE is highly sensitive to climate change and provides fresh water for much of the world population. Snowmelt from mountainous regions represents the dominant water source for 60 million people in the United States and over one billion people globally. Determination of snow grain sizes comprising mountain snowpack is critical for predicting snow meltwater runoff, understanding physical properties and radiation balance, and providing necessary input for interpreting satellite measurements. Both microwave emission and radar backscatter from the snow are dominated by the snow grain size stratigraphy. As a result, retrieval algorithms for measuring snow water equivalents from orbiting satellites is largely hindered by inadequate knowledge of grain size.

Current techniques for measuring grain size include near-infrared photography and contact spectroscopy, both of which significantly disturb the snowpack and require many hours of labor to obtain a single measurement that is extrapolated with great error. To accurately determine the SWE and predict meltwater runoff, the grain size profile (from surface to ground) must be known at many points over a large geographical area, which is not practical with current techniques.

A prototype compact probe was developed that can be inserted into the snowpack to rapidly measure grain size without the need for digging a snowpit. The probe is portable and can be easily transported to take many measurements over a large area. The probe sends into the snowpack an optical package consisting of an optical infrared reflectance probe with near right-angle mirror, an optical camera, and a light source. In typical field operation, a standard federal snow sampler is used to drill a 2-in. ( $\approx 5$ -cm)-diameter hole vertically into the snow and re-



The main components of the **Spectral Profiler Probe** include an optical fiber bundle that carries the light to a spectrometer on the surface, which records the reflectance spectrum. A manual clamping mechanism mounted to the top of the sleeve allows the user to move the shaft up and down and clamp in place during each measurement.

move the core. A thin aluminum sleeve (comprised of tubing assembled in sections) is then inserted into the empty hole. The probe optical package is then lowered inside the sleeve by an aluminum shaft, assembled in sections. The sleeve has a machined slot running the length of the sleeve, except at the joints, allowing the probe optics to view the snow surface horizontally through the slot.

The reflectance probe couples light reflected from the snow surface into an optical fiber bundle that carries the light to a spectrometer on the surface, which records the reflectance spectrum. A manual clamping mechanism mounted to the top of the sleeve allows the user to move the shaft up and down and clamp in place during each measurement. Vertical location measurement is accomplished manually by observing the align-

ment of centimeter graduation markings on the shaft with the top of the clamping mechanism.

The fiber optic bundle coming from the reflectance probe is bifurcated as it comes out of the probe, so that two separate cables go to the surface. One cable connects to the spectrometer, and the other cable connects to another light source on the surface. With this configuration, two different modes of operation are possible. In the first, the external light source is not energized, and the internal light source on the probe tip is energized, shining directly onto the snow surface. This provides strong lighting and is preferable to use under low reflectance conditions, such as large crystals in the snow or large amounts of contamination. The second mode uses the external light source through the fiber optic cable and does

not use the in-bore light. This mode couples less heat into the snow and eliminates any melting concern due to the light source.

The probe provides approximately 1 cm vertical spatial resolution for measuring the stratigraphy. Grain size is determined by integrating the normalized 1,020-nm absorption feature in the ice reflectance spectrum and comparing it to a lookup table generated from an optical scattering model of uniform ice spheres.

The entire probe assembly can be dismantled and stowed into a large backpack for cross-country transport over large distances.

*This work was done by Daniel F. Berisford, Noah P. Molotch, and Thomas Painter of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47992*

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## Portable Fourier Transform Spectroscopy for Analysis of Surface Contamination and Quality Control

*Goddard Space Flight Center, Greenbelt, Maryland*

Progress has been made into adapting and enhancing a commercially available infrared spectrometer for the development of a handheld device for in-field measurements of the chemical composition of various samples of materials. The intent is to duplicate the functionality of a benchtop Fourier transform infrared spectrometer (FTIR) within the compactness of a handheld instrument with significantly improved spectral responsivity.

Existing commercial technology, like the deuterated L-alanine triglycine sulfide detectors (DLATGS), is capable of

sensitive in-field chemical analysis. This proposed approach compares several subsystem elements of the FTIR inside of the commercial, non-benchtop system to the commercial benchtop systems. These subsystem elements are the detector, the preamplifier and associated electronics of the detector, the interferometer, associated readout parameters, and cooling.

This effort will examine these different detector subsystem elements to look for limitations in each. These limitations will be explored collaboratively with the commercial provider, and will

be prioritized to meet the deliverable objectives. The tool design will be that of a handheld gun containing the IR filament source and associated optics. It will operate in a "point-and-shoot" manner, pointing the source and optics at the sample under test and capturing the reflected response of the material in the same handheld gun. Data will be captured via the gun and ported to a laptop.

*This work was done by Diane Pugel of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16002-1*

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## In Situ Geochemical Analysis and Age Dating of Rocks Using Laser Ablation-Miniature Mass Spectrometer

**Instrument offers a more quantitative assessment of elemental composition than techniques that detect laser-ionized species produced directly in the ablation process.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A miniaturized instrument for performing chemical and isotopic analysis of rocks has been developed. The rock sample is ablated by a laser and the neutral species produced are analyzed using the JPL-invented miniature mass spectrom-

eter. The direct sampling of neutral ablated material and the simultaneous measurement of all the elemental and isotopic species are the novelties of this method.

In this laser ablation-miniature mass spectrometer (LA-MMS) method, the

ablated neutral atoms are led into the electron impact ionization source of the MMS, where they are ionized by a 70-eV electron beam. This results in a secondary ion pulse typically 10–100- $\mu$ s wide, compared to the original 5–10-ns

laser pulse duration. Ions of different masses are then spatially dispersed along the focal plane of the magnetic sector of the miniature mass spectrometer and measured in parallel by a modified CCD (charge-coupled device) array detector capable of detecting ions directly. Compared to conventional scanning techniques, simultaneous measurement of the ion pulse along the focal plane effectively offers a 100% duty cycle over a wide mass range. LA-MMS offers a more quantitative assessment of elemental composition than techniques that detect laser-ionized species produced directly in the abla-

tion process because the latter can be strongly influenced by matrix effects that vary with the structure and geometry of the surface, the laser beam, and the ionization energies of the elements. The measurement of high-precision isotopic ratios and elemental composition of different rock minerals by LA-MMS method has been demonstrated. The LA-MMS can be applied for the absolute age determination of rocks. There is no such instrument available presently in a miniaturized version that can be used for NASA space missions. Work is in progress in the laboratory for geochronology of rocks using LA-MMS

that is based on K-Ar radiogenic dating technique.

Besides the MMS that has a double focusing focal plane geometry and a modified-CCD array ion-detector, the major components of the instrument include the laser, pumping, and its housing subsystem. These have been miniaturized for other NASA missions and when combined with the LA-MMS, make the instrument deployable on a rover or lander.

*This work was done by Mahadeva P. Sinha, Michael H. Hecht, and Joel A. Hurowitz of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48250*

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## Physics Mining of Multi-Source Data Sets

*Goddard Space Flight Center, Greenbelt, Maryland*

Powerful new parallel data mining algorithms can produce diagnostic and prognostic numerical models and analyses from observational data. These techniques yield higher-resolution measures than ever before of environmental parameters by fusing synoptic imagery and time-series measurements. These techniques are general and relevant to observational data, including raster, vector, and scalar, and can be applied in all Earth- and environmental-science domains. Because they can be highly automated and are parallel, they scale to large spatial domains and are well suited to change and gap detection. This makes it possible to analyze spatial and temporal gaps in information, and facilitates within-mission re-planning to optimize the allocation of observational resources.

The basis of the innovation is the extension of a recently developed set of algorithms packaged into MineTool to multi-variate time-series data. MineTool is

unique in that it automates the various steps of the data mining process, thus making it amenable to autonomous analysis of large data sets. Unlike techniques such as Artificial Neural Nets, which yield a blackbox solution, MineTool's outcome is always an analytical model in parametric form that expresses the output in terms of the input variables. This has the advantage that the derived equation can then be used to gain insight into the physical relevance and relative importance of the parameters and coefficients in the model. This is referred to as "physics-mining of data." The capabilities of MineTool are extended to include both supervised and unsupervised algorithms, handle multi-type data sets, and parallelize it.

The innovations include: (1) Physics mining algorithms, enabling derivation of analytical relations and physical models from observational data; (2) Automated, parallel algorithms, enabling a high degree of automation and paral-

lization, scaling to large spatial domains well-suited to change and gap detection; (3) Local versus global modeling, to generate locally optimal models appropriate to a specific geospatial region accounting for the unique setting and conditions; (4) Fusion of multi-source, multi-type data that yield higher-resolution measures than ever before by fusing synoptic imagery and independent time-series measurements; and (5) Calculation of Palmer's Drought Severity Index Analogue.

Successful completion of this project will lead to a major breakthrough in the climate study in particular, and to analysis of multi-source data as applied to the hydrologic cycle affecting climate change impacts and resource management.

*This work was done by John Helly, Homa Karimabadi, and Tamara Sipes of SciberQuest, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15802-1*

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## Photogrammetry Tool for Forensic Analysis

**This acquires visual crime and accident scene data for later processing.**

*John F. Kennedy Space Center, Florida*

A system allows crime scene and accident scene investigators the ability to acquire visual scene data using cameras for processing at a later time. This system uses a COTS digital camera, a photogrammetry calibration cube, and 3D

photogrammetry processing software.

In a previous instrument developed by NASA, the laser scaling device made use of parallel laser beams to provide a photogrammetry solution in 2D. This device and associated software work well under

certain conditions. In order to make use of a full 3D photogrammetry system, a different approach was needed.

When using multiple cubes, whose locations relative to each other are unknown, a procedure that would merge the

data from each cube would be as follows:

1. One marks a reference point on cube 1, then marks points on cube 2 as unknowns. This locates cube 2 in cube 1's coordinate system.
2. One marks reference points on cube 2, then marks points on cube 1 as unknowns. This locates cube 1 in cube 2's coordinate system.
3. This procedure is continued for all combinations of cubes.

4. The coordinate of all of the found coordinate systems is then merged into a single global coordinate system.

In order to achieve maximum accuracy, measurements are done in one of two ways, depending on scale: when measuring the size of objects, the coordinate system corresponding to the nearest cube is used, or when measuring the location of objects relative to a global coordinate system, a merged coordinate system is used.

Presently, traffic accident analysis is time-consuming and not very accurate. Using cubes with differential GPS would give absolute positions of cubes in the accident area, so that individual cubes would provide local photogrammetry calibration to objects near a cube.

*This work was done by John Lane of ASRC Aerospace for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-12975*



## Connect Global Positioning System RF Module

This is a GPS software-defined radio down-converter for the ISS. NASA's Jet Propulsion Laboratory, Pasadena, California

The CoNNeCT Global Positioning System RF Module (GPSM) slice is part of the JPL CoNNeCT Software Defined Radio (SDR). CoNNeCT is the Communications, Navigation, and Networking reconfigurable Testbed project that is part of NASA's Space Communication and Navigation (SCaN) Program. The CoNNeCT project is an experimental demonstration that will lead to the advancement of SDRs and provide a path for new space communication and navigation systems for future NASA exploration missions. The JPL CoNNeCT SDR will be flying on the International Space Station (ISS) in 2012 in support of the SCaN CoNNeCT program.

The GPSM is a radio-frequency sampler module (see Figure 1) that directly sub-harmonically samples the filtered GPS L-band signals at L1 (1575.42 MHz), L2 (1227.6 MHz), and L5 (1176.45 MHz). The JPL SDR receives GPS signals through a Dorne & Margolin antenna mounted onto a choke ring. The GPS signal is filtered against interference, amplified, split, and fed into three channels: L1, L2, and L5. In each of the L-band channels, there is a chain of bandpass filters and amplifiers, and the signal is fed through each of these channels to where the GPSM performs a one-bit analog-to-digital conversion (see Figure 2). The GPSM uses a sub-harmonic, single-bit L1, L2, and L5 sampler that samples at a clock rate of 38.656 MHz.

The new capability is the down-conversion and sampling of the L5 signal when previous hardware did not provide this capability. The first GPS IIF Satellite was launched in 2010, providing the new L5 signal. With the JPL SDR flying on the ISS, it will be possible to demonstrate navigation solutions with 10-meter 3-D accuracy at 10-second intervals using a field-programmable gate array (FPGA)-based feedback loop running at 50 Hz. The GPS data bits will be decoded and used in the SDR. The GPSM will also allow other "waveforms" that are installed in

the SDR to demonstrate various GNSS tracking techniques.

This work was done by Garth W. Franklin, Lawrence E. Young, Michael A. Ciminera, Jeffrey Y. Tien, Jacob Gorelik, Brian Bachman

Okihiro, and Cynthia L. Koelewyn of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47764

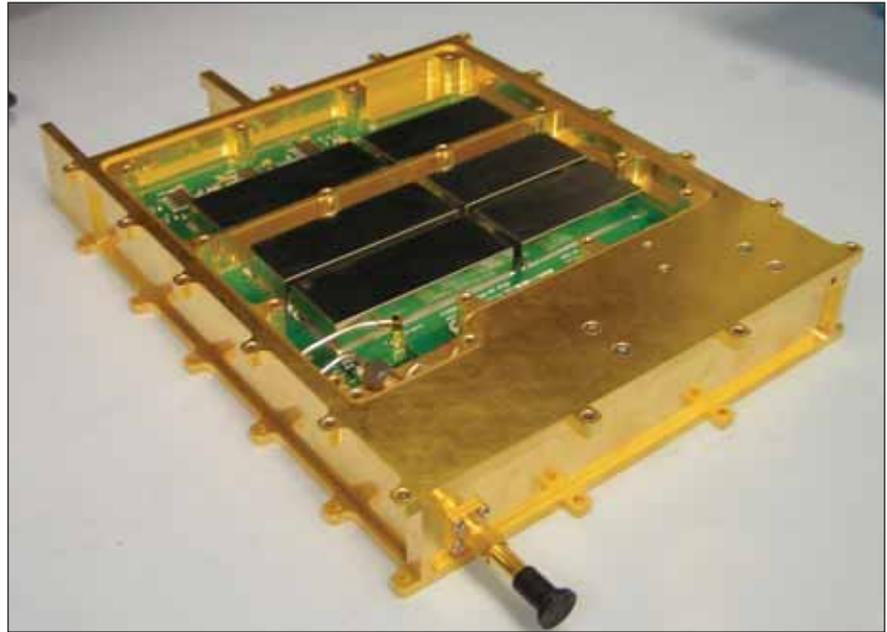


Figure 1. JPL CoNNeCT GPSM

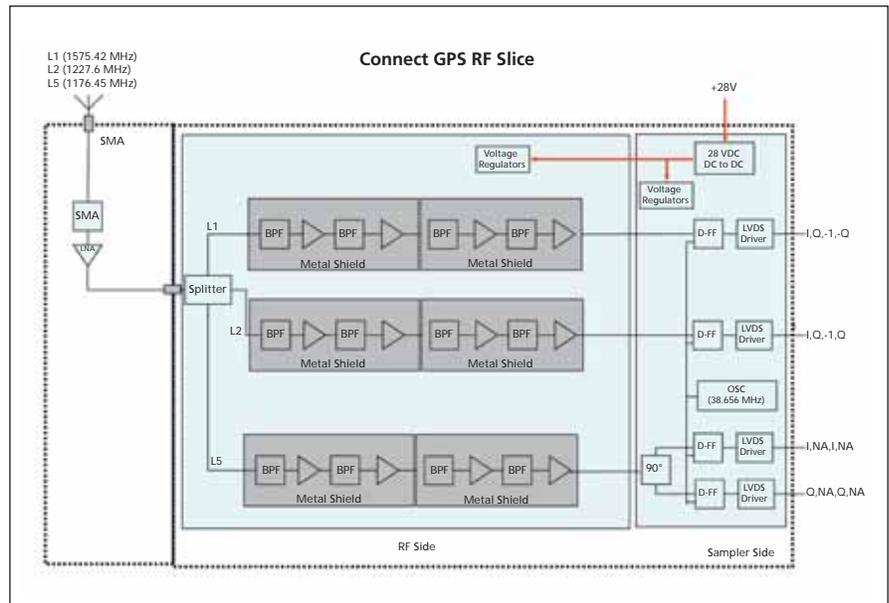


Figure 2. JPL CoNNeCT SDR Block Diagram

## Simple Cell Balance Circuit

Lyndon B. Johnson Space Center, Houston, Texas

A method has been developed for continuous cell voltage balancing for rechargeable batteries (e.g. lithium ion batteries). A resistor divider chain is provided that generates a set of voltages representing the ideal cell voltage (the voltage of each cell should be as if the cells were perfectly balanced). An operational-amplifier circuit with an added current buffer stage generates the ideal voltage with a very high degree of accuracy, using the concept of negative feedback.

The ideal voltages are each connected to the corresponding cell through a current-limiting resistance. Over time, having the cell connected to the ideal voltage provides a balancing current that moves the cell voltage very close to that ideal level. In effect, it adjusts the cur-

rent of each cell during charging, discharging, and standby periods to force the cell voltages to be equal to the ideal voltages generated by the resistor divider. The device also includes solid-state switches that disconnect the circuit from the battery so that it will not discharge the battery during storage.

This solution requires relatively few parts and is, therefore, of lower cost and of increased reliability due to the fewer failure modes. Additionally, this design uses very little power. A preliminary model predicts a power usage of 0.18 W for an 8-cell battery. This approach is applicable to a wide range of battery capacities and voltages.

*This work was done by Steven D. Johnson, Jerry W. Byers, and James A. Martin of Lock-*

*heed Martin Space Systems for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to Lockheed Martin Space Systems. Inquiries concerning licenses for its commercial development should be addressed to:*

*David P. Wood, Esq.*

*General Counsel, Intellectual Property*

*Lockheed Martin Space Systems Company*

*P.O. Box 179, MS 5120*

*Denver, CO 80201-0179*

*Refer to MSC-24673-1, volume and number of this NASA Tech Briefs issue, and the page number.*

## Miniature EVA Software Defined Radio

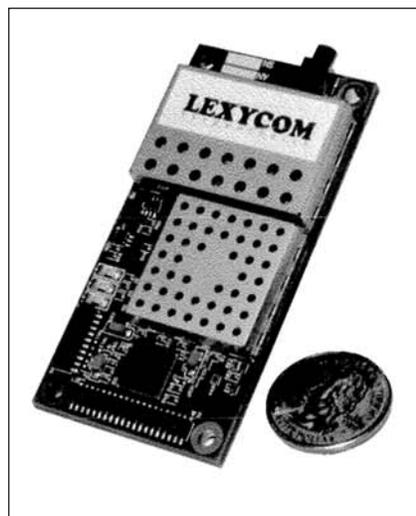
**This technology can be used in homeland security applications, industrial/power plants, traffic and transportation systems, and by first responders.**

Lyndon B. Johnson Space Center, Houston, Texas

As NASA embarks upon developing the Next-Generation Extra Vehicular Activity (EVA) Radio for deep space exploration, the demands on EVA battery life will substantially increase. The number of modes and frequency bands required will continue to grow in order to enable efficient and complex multi-mode operations including communications, navigation, and tracking applications.

Whether conducting astronaut excursions, communicating to soldiers, or first responders responding to emergency hazards, NASA has developed an innovative, affordable, miniaturized, power-efficient software defined radio that offers unprecedented power-efficient flexibility. This lightweight, programmable, S-band, multi-service, frequency-agile EVA software defined radio (SDR) supports data, telemetry, voice, and both standard and high-definition video. Features include a modular design, an easily scalable architecture, and the EVA SDR allows for both stationary and mobile battery powered handheld operations.

Currently, the radio is equipped with an S-band RF section. However, its scalable architecture can accommodate



The EVA Software Defined Radio.

multiple RF sections simultaneously to cover multiple frequency bands. The EVA SDR also supports multiple network protocols. It currently implements a Hybrid Mesh Network based on the 802.11s open standard protocol. The radio targets RF channel data rates up to 20 Mbps and can be equipped with a real-time operating system (RTOS) that

can be switched off for power-aware applications. The EVA SDR's modular design permits implementation of the "same hardware at all Network Nodes" concept. This approach assures the portability of the same software into any radio in the system. It also brings several benefits to the entire system including reducing system maintenance, system complexity, and development cost.

This software-defined radio is under 3 in.<sup>3</sup> (49 cm<sup>3</sup>) and weighs less than 4 oz. (113 g) with a power consumption averaging at 3 W (see figure). The EVA SDR design incorporates several innovations aimed at miniaturization without sacrificing any of its capabilities and still maintaining the lowest possible power consumption.

The SDR implements a range of technological solutions to achieve this goal. For instance, the SDR's hardware and software were designed as a whole as opposed to being selected separately. In short, the hardware components were selected such that they can be heavily guided by the SDR's software in order to minimize their power consumption. Additionally, the EVA SDR utilizes Lexycom's Hardware Synergy Concept. Per

this concept, the transceiver's software divides the computational tasks performed by the device into small sub-tasks and designates these tasks to the most suitable hardware module for the task. In a sense, the SDR's software performs micromanagement of the computed tasks well below the commonly used level of task assignment.

The EVA SDR also incorporates a dynamic waveform selection algorithm that minimizes the SDR's power consumption based on the channel QoS. To do so, the SDR collects the channel characteristics on a regular basis while in the

normal mode of operation and adjusts the modulation type, RF channel data rate, output power level, and some other characteristics of the transmitted signal based on the gathered QoS. This method results in, essentially, 1000s of continuously changing waveforms.

In sum, the EVA SDR bridges the gap that has historically inhibited the coexistence of flexibility, power efficiency, and miniaturization in the same mobile handset radio.

*This work was done by Aleksey Pozhidaev of Lexycom Technologies for Johnson Space Center. For further information, contact the*

*JSC Innovation Partnerships Office at (281) 483-3809.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Lisa Livdahl, CFO  
Lexycom Technologies, Inc.  
425 South Bowen Street, Unit 1  
Longmont, CO 80501  
Phone No.: (303) 774-7822  
URL: www.lexycominc.com*

*Refer to MSC-25125-1, volume and number of this NASA Tech Briefs issue, and the page number.*

## Remotely Accessible Testbed for Software Defined Radio Development

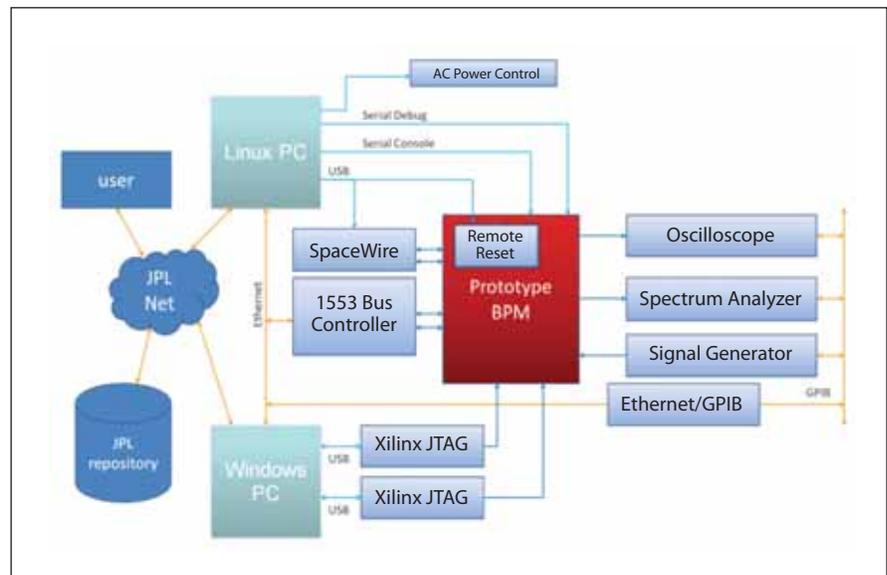
**This testbed enables a geographically scattered development team to collaborate on a testbed.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Previous development testbeds have assumed that the developer was physically present in front of the hardware being used. No provision for remote operation of basic functions (power on/off or reset) was made, because the developer/operator was sitting in front of the hardware, and could just push the button manually. In this innovation, a completely remotely accessible testbed has been created, with all diagnostic equipment and tools set up for remote access, and using standardized interfaces so that failed equipment can be quickly replaced. In this testbed, over 95% of the operating hours were used for testing without the developer being physically present.

The testbed includes a pair of personal computers, one running Linux and one running Windows. A variety of peripherals is connected via Ethernet and USB (universal serial bus) interfaces. A private internal Ethernet is used to connect to test instruments and other devices, so that the sole connection to the "outside world" is via the two PCs.

An important design consideration was that all of the instruments and interfaces used stable, long-lived industry standards, such as Ethernet, USB, and GPIB (general purpose interface bus). There are no "plug-in" cards for the two PCs, so there are no problems with finding replacement computers with matching interfaces, device drivers, and installation. The only thing unique



The Remotely Accessible Testbed includes a pair of personal computers with a variety of peripherals connected via Ethernet and USB interfaces.

to the two PCs is the locally developed software, which is not specific to computer or operating system version. If a device (including one of the computers) were to fail or become unavailable (e.g., a test instrument needed to be recalibrated), replacing it is a straightforward process with a standard, off-the-shelf device.

This strategy has paid off several times over the developmental effort. It made it very easy to construct a "portable" version of the testbed to take to a remote site to test the flight

model radio: the two PCs were rented laptops, and copies of the required interface boxes were rented or borrowed. Everything was plugged together, the software was loaded, and a few hours later, testing could commence. Compared to the traditional approach of a rack full of customized interface drawers and customized PCs, it was much simpler and less expensive, as well as immediately responsive to changing project needs.

In fact, the experience of creating an *ad hoc* test capability at a remote site has

resulted in some minor changes to the overall design: for example, rather than individual serial ports, the system now uses USB to serial adapters, all plugged into a USB hub, so there is a single USB

connection to the Linux PC. Likewise, in the laptop configuration, the private internal network is implemented with USB-Ethernet adapters, because most laptops come with only one Ethernet interface.

*This work was done by James P. Lux, Minh Lang, Kenneth J. Peters, and Gregory H. Taylor of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48013*



## **System-of-Systems Technology-Portfolio- Analysis Tool**

Advanced Technology Life-cycle Analysis System (ATLAS) is a system-of-systems technology-portfolio-analysis software tool. ATLAS affords capabilities to (1) compare estimates of the mass and cost of an engineering system based on competing technological concepts; (2) estimate life-cycle costs of an outer-space-exploration architecture for a specified technology portfolio; (3) collect data on state-of-the-art and forecasted technology performance, and on operations and programs; and (4) calculate an index of the relative programmatic value of a technology portfolio. ATLAS facilitates analysis by providing a library of analytical spreadsheet models for a variety of systems. A single analyst can assemble a representation of a system of systems from the models and build a technology portfolio. Each system model estimates mass, and life-cycle costs are estimated by a common set of cost models.

Other components of ATLAS include graphical-user-interface (GUI) software, algorithms for calculating the aforementioned index, a technology database, a report generator, and a form generator for creating the GUI for the system models. At the time of this reporting, ATLAS is a prototype, embodied in Microsoft Excel and several thousand lines of Visual Basic for Applications that run on both Windows and Macintosh computers.

*This program was written by Daniel O'Neil of Marshall Space Flight Center, John Mankins of NASA Headquarters, and Harvey Feingold and Wayne Johnson of Science Applications International Corp. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32291-1*

## **VESGEN Software for Mapping and Quantification of Vascular Regulators**

VESSEL GENeration (VESGEN) Analysis is an automated software that maps and quantifies effects of vascular regulators on vascular morphology by

analyzing important vessel parameters. Quantification parameters include vessel diameter, length, branch points, density, and fractal dimension. For vascular trees, measurements are reported as dependent functions of vessel branching generation.

VESGEN maps and quantifies vascular morphological events according to fractal-based vascular branching generation. It also relies on careful imaging of branching and networked vascular form. It was developed as a plug-in for ImageJ (National Institutes of Health, USA). VESGEN uses image-processing concepts of 8-neighbor pixel connectivity, skeleton, and distance map to analyze 2D, black-and-white (binary) images of vascular trees, networks, and tree-network composites. VESGEN maps typically 5 to 12 (or more) generations of vascular branching, starting from a single parent vessel. These generations are tracked and measured for critical vascular parameters that include vessel diameter, length, density and number, and tortuosity per branching generation. The effects of vascular therapeutics and regulators on vascular morphology and branching tested in human clinical or laboratory animal experimental studies are quantified by comparing vascular parameters with control groups.

VESGEN provides a user interface to both guide and allow control over the users' vascular analysis process. An option is provided to select a morphological tissue type of vascular trees, network or tree-network composites, which determines the general collections of algorithms, intermediate images, and output images and measurements that will be produced.

VESGEN was used to map and quantify progression of human diabetic retinopathy (DR), a vascular disease that is the major cause of blindness in working-aged adults. VESGEN maps and quantifies site-specific characteristics such as vessel diameter, number, and length based on bifurcated generational branching within retinal arterial and venous trees. To analyze ophthalmic clinical images of the human retina as a new VESGEN modification, VESGEN was modified to detect and analyze the first branching generation (parent) vessel when that vessel originates at a region of interest (ROI) located within the image

(not just at the edge of an image, as for previous VESGEN studies). Other applications include remodeling coronary vessels, tumor vessels, rodent retinal experiments, gastrointestinal inflammation, and cytokine or drug regulation in *in vivo* models.

VESGEN also can be used for the mapping and quantification of remodeling of plant leaf venation patterns in response to plant growth, genetic engineering, and other growth perturbants. Providing VESGEN as a plug-in also makes it easily distributable, able to be run on many computer platforms, and readily utilized by other researchers.

*This work was done by Patricia A. Parsons-Wingenter, Mary B. Vickerman, and Patricia A. Keith 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-18722-1/3-1/4-1.*

## **Constructing a Database From Multiple 2D Images for Camera Pose Estimation and Robot Localization**

The LMDB (Landmark Database) Builder software identifies persistent image features ("landmarks") in a scene viewed multiple times and precisely estimates the landmarks' 3D world positions. The software receives as input multiple 2D images of approximately the same scene, along with an initial guess of the camera poses for each image, and a table of features matched pair-wise in each frame. LMDB Builder aggregates landmarks across an arbitrarily large collection of frames with matched features. Range data from stereo vision processing can also be passed to improve the initial guess of the 3D point estimates. The LMDB Builder aggregates feature lists across all frames, manages the process to promote selected features to landmarks, and iteratively calculates the 3D landmark positions using the current camera pose estimations (via an optimal ray projection method), and then improves the camera pose estimates

using the 3D landmark positions. Finally, it extracts image patches for each landmark from auto-selected key frames and constructs the landmark database. The landmark database can then be used to estimate future camera poses (and therefore localize a robotic vehicle that may be carrying the cameras) by matching current imagery to landmark database image patches and using the known 3D landmark positions to estimate the current pose.

*This work was done by Michael Wolf, Adnan I. Ansar, Shane Brennan, Daniel S. Clouse, and Curtis W. Padgett of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-47845.*

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### ➤ **Adaption of G-TAG Software for Validating Touch and Go Asteroid Sample Return Design Methodology**

A software tool is used to demonstrate the feasibility of Touch and Go (TAG) sampling for Asteroid Sample Return missions. TAG is a concept whereby a spacecraft is in contact with the surface of a small body, such as a comet or asteroid, for a few seconds or less before ascending to a safe location away from the small body. Previous work at JPL developed the G-TAG simulation tool, which provides a software environment for fast, multi-body simulations of the TAG event. G-TAG is described in "Multibody Simulation Software Testbed for Small-Body Exploration and Sampling," (NPO-47196) *NASA Tech Briefs*, Vol. 35, No. 11 (November 2011), p.54. This current innovation adapts this tool to a mission that intends to return a sample from the surface of an asteroid.

In order to demonstrate the feasibility of the TAG concept, the new software tool was used to generate extensive simulations that demonstrate the designed spacecraft meets key requirements. These requirements state that contact force and duration must be sufficient to ensure that enough material from the surface is collected in the brushwheel sampler (BWS), and that the spacecraft must survive the contact and must be able to recover and ascend to a safe position, and maintain velocity and orientation after the contact.

*This work was done by Lars James C. Blackmore, Behcet Acikmese, and Milan Mandic of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-47193.*

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### ➤ **3D Visualization for Phoenix Mars Lander Science Operations**

Planetary surface exploration missions present considerable operational challenges in the form of substantial communication delays, limited communication windows, and limited communication bandwidth. A 3D visualization software was developed and delivered to the 2008 Phoenix Mars Lander (PML) mission. The components of the system include an interactive 3D visualization environment called "Mercator," terrain reconstruction software called the "Ames Stereo Pipeline," and a server providing distributed access to terrain models. The software was successfully utilized during the mission for science analysis, site understanding, and science operations activity planning.

A "terrain server" was implemented that provided distribution of terrain models from a central repository to clients running the Mercator software. The Ames Stereo Pipeline generates accurate, high-resolution, texture-mapped, 3D terrain models from stereo image pairs. These terrain models can then be visualized within the Mercator environment. The central crosscutting goal for these tools is to provide an easy-to-use, high-quality, full-featured visualization environment that enhances the mission science team's ability to develop low-risk productive science activity plans. In addition, for the Mercator and Viz visualization environments, extensibility and adaptability to different missions and application areas are key design goals.

Mercator is a cross-platform, adaptable, extensible, interactive 3D visualization software tool that enables users to manipulate and interrogate a simulated 3D environment. It is implemented in the Java programming language to be compatible with Ensemble, a NASA-developed ground data systems software component framework based on the Eclipse open source platform.

The Mercator User Interface (UI) is

divided into a number of tiles or "elements," presenting control panels and views into the 3D scene. The central UI element is an interactive 3D viewer with site interrogation and analysis capabilities. Each UI element can be repositioned, resized, iconified, or dragged out of the window frame.

In an effort to achieve simple, natural interactions, object-oriented, direct manipulation techniques were chosen where practical, and persistent user interface modes were minimized. For example, to measure distances, the user manipulates a 3D representation of a measuring tool in the scene. There is no explicit mode of measurement, and the user can continue to interact with the 3D environment (e.g., changing the viewpoint) as usual.

*This work was done by Laurence Edwards, Leslie Keely, David Lees, and Carol Stoker of Ames Research Center. Further information is contained in a TSP (see page 1). ARC-16434-1*

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### ➤ **RxGen General Optical Model Prescription Generator**

RxGen is a prescription generator for JPL's in-house optical modeling software package called MACOS (Modeling and Analysis for Controlled Optical Systems), which is an expert optical analysis software package focusing on modeling optics on dynamic structures, deformable optics, and controlled optics.

The objectives of RxGen are to simplify and automate MACOS prescription generations, reducing errors associated with creating such optical prescriptions, and improving user efficiency without requiring MACOS proficiency. RxGen uses MATLAB (a high-level language and interactive environment developed by MathWorks) as the development and deployment platform, but RxGen can easily be ported to another optical modeling/analysis platform.

Running RxGen within the modeling environment has the huge benefit that variations in optical models can be made an integral part of the modeling state. For instance, optical prescription parameters determined as external functional dependencies, optical variations by controlling the in-/exclusion of optical components like sub-systems, and/or controlling the state of all components.

Combining the mentioned capabilities and flexibilities with RxGen's optical abstraction layer completely elimi-

nates the hindering aspects for requiring proficiency in writing/editing MACOS prescriptions, allowing users to focus on the modeling aspects of optical systems, i.e., increasing productivity and efficiency. RxGen provides significant

enhancements to MACOS and delivers a framework for fast prototyping as well as for developing very complex controlled optical systems.

*This work was done by Norbert Sigrist of Caltech for NASA's Jet Propulsion Laboratory.*

*For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov).*

*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-48000.*





## Carbon Nanotube Bonding Strength Enhancement Using Metal “Wicking” Process

*NASA’s Jet Propulsion Laboratory, Pasadena, California*

Carbon nanotubes grown from a surface typically have poor bonding strength at the interface. A process has been developed for adding a metal coat to the surface of carbon nanotubes (CNTs) through a “wicking” process, which could lead to an enhanced bonding strength at the interface. This process involves merging CNTs with indium as a bump-bonding enhancement.

Classical capillary theory would not normally allow materials that do not

“wet” carbon or graphite to be drawn into the spacings by capillary action because the contact angle is greater than 90°. However, capillary action can be induced through JPL’s ability to fabricate oriented CNT bundles to desired spacings, and through the use of deposition techniques and temperature to control the size and mobility of the liquid metal streams and associated reservoirs. A reflow and plasma cleaning process has also been developed and demonstrated

to remove indium oxide, and to obtain smooth coatings on the CNT bundles.

*This work was done by James L. Lamb, Matthew R. Dickie, Robert S. Kowalczyk, and Anna Liao of Caltech; and Michael J. Bronikowski of Atomate Corporation for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46594*

## Multi-Layer Far-Infrared Component Technology

*Goddard Space Flight Center, Greenbelt, Maryland*

A method has been developed for fabricating high-reflectivity, multi-layer optical films for the terahertz wavelength region. A silicon mirror with 99.997-percent reflectivity at 70  $\mu\text{m}$  wavelength requires an air gap of 17.50  $\mu\text{m}$ , and a silicon thickness of 5.12  $\mu\text{m}$ . This approach obtains pre-thinned wafers of about 20 mm thickness in

order to measure their thickness precisely. A gold annulus of appropriate thickness is deposited to reach the required total thickness. This, in turn, has the central aperture etched down to the desired final silicon thickness. Also, the novel Bragg stack optics in this innovation are key to providing Fabry-Perot spectroscopy and improved spectral

component technologies of unprecedented resolution, free spectral range, and aperture.

*This work was done by Oliver Edwards of Zyberwear for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15888-1*

## Germanium Lift-Off Masks for Thin Metal Film Patterning

**This innovation has uses in the fabrication of transition edge sensors and microwave kinetic inductance detectors.**

*Goddard Space Flight Center, Greenbelt, Maryland*

A technique has been developed for patterning thin metallic films that are, in turn, used to fabricate microelectronics circuitry and thin-film sensors. The technique uses germanium thin films as lift-off masks. This requires development of a technique to strip or undercut the germanium chemically without affecting the deposited metal. Unlike in the case of conventional polymeric lift-off masks, the substrate can be exposed to very high temperatures during processing (sputter deposition). The reason why polymeric lift-off masks cannot be exposed to very high temperatures (>100 °C) is be-

cause (a) they can become cross linked, making lift-off very difficult if not impossible, and (b) they can outgas nitrogen and oxygen, which then can react with the metal being deposited. Consequently, this innovation is expected to find use in the fabrication of transition edge sensors and microwave kinetic inductance detectors, which use thin superconducting films deposited at high temperature as their sensing elements.

Transition edge sensors, microwave kinetic inductance detectors, and their circuitry are comprised of superconducting thin films, for example Nb and TiN.

Reactive ion etching can be used to pattern these films; however, reactive ion etching also damages the underlying substrate, which is unwanted in many instances. Polymeric lift-off techniques permit thin-film patterning without any substrate damage, but they are difficult to remove and the polymer can outgas during thin-film deposition. The outgassed material can then react with the film with the consequence of altered and non-reproducible materials properties, which, in turn, is deleterious for sensors and their circuitry.

The purpose of this innovation was to fabricate a germanium lift-off mask to be

used for patterning thin metal films. The germanium can either be thermally or electron-beam evaporated onto Si(001) wafers. The evaporation rates and deposited thicknesses are 0.2 nm/s and 0.5 nm/s, and 620 nm and 500 nm for thermal and electron beam evaporation, respectively. The germanium can be patterned either via polymeric lift-off, using 1 micron of LOR-5a (Microchem) and 1.3 microns of S-1811 (Shipley) photoresist,

or with lithographic patterning using 1.3 microns of S-1811 photoresist. In both cases, the photoresist is exposed to UV light using a mask aligner (MA-6, SUSS) and developed in a commercially available developer. In the case of lift-off, the germanium is removed in 1165 (Microchem); in the case of lithographic patterning, the germanium is removed in a dilute hydrochloric acid solution. The photoresist can be stripped in acetone.

The desired metal thin film (Nb, TiN, NbN, Au) is deposited and is lifted-off in dilute hydrochloric acid. The reliability of the lift-off process is dependent upon the amount of undercut in the germanium mask during the germanium patterning process.

*This work was done by Ari Brown of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16147-1*



## Sealing Materials for Use in Vacuum at High Temperatures

**These materials retain favorable handling properties in vacuum for usefully long times.**

*Lyndon B. Johnson Space Center, Houston, Texas*

Sealing materials that can be applied and left in place in vacuum over a wide range of temperatures (especially temperatures of a few thousand degrees Celsius) have been conceived and investigated for potential utility in repairing thermal-protection tiles on the space shuttles in orbit before returning to Earth. These materials are also adaptable to numerous terrestrial applications that involve vacuum processing and/or repair of structures that must withstand high temperatures. These materials can be formulated to have mechanical handling characteristics ranging from almost freely flowing liquid-like consistency through paste-like consistency to stiff puttylike consistency, and to retain these characteristics in vacuum until heated to high curing temperatures.

A sealing material of this type can be formulated to be used in any of several different ways — for example, to be impregnated into a high-temperature-fabric patch, impregnated into a high-temperature-fabric gasket for sealing a patch, applied under a patch, or applied alone in the manner of putty or wallboard compound. The sealing material must be formulated to be compat-

ible with, and adhere to, the structural material(s) to be repaired. In general, the material consists of a vacuum-compatible liquid containing one or more dissolved compound(s) and/or mixed with suspended solid particles.

Depending on the intended application, the liquid can be chosen to be of a compound that can remain in place in vacuum for a time long enough to be useful, and/or to evaporate or decompose in a controlled way to leave a useful solid residue behind. The evaporation rate is determined by proper choice of vapor pressure, application of heat, and/or application of ultraviolet light or other optical radiation. The liquid chosen for the original space shuttle application is a commercial silicone vacuum-pump oil.

The solids are chosen to contribute desired properties to the residue. The solids can be obtained in the form of fine powders prior to suspension and/or dissolution in the liquid; alternatively or in addition, solid particles can be generated from chemical reactions as the liquid evaporates and/or decomposes. The relative amounts of solid and liquid are chosen to obtain the desired consistency. The liquid and solids are mixed thoroughly in

air at room temperature. To prevent bubbling, foaming, and swelling during application in vacuum, the mixture must be degassed by heating in a vacuum oven at a temperature of 90 °C for at least 4 hours, then stored, until use, in a water- and gas-impermeable container.

In a typical case, the solids can include (1) the ingredients of a frit or bonding phase (e.g., a low-melting-temperature glass) that melts at a temperature expected to be encountered in use, and (2) a refractory compound (e.g., SiC fibers mixed with irregularly shaped SiC particles) that does not melt at the expected maximum temperature. Upon heating after application, the liquid evaporates or decomposes and the solids form a refractory residue held together by the surface tension of the glass phase while at and above the glass-formation temperature. After cooling to lower temperature, the residue remains bonded together by the solid glass.

*This work was done by Donald R. Pettit and Charles J. Camarda of Johnson Space Center, and Wallace Lee Vaughn of Langley Research Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23959-1*

## Radiation Shielding System Using a Composite of Carbon Nanotubes Loaded With Electropolymers

**A lightweight and replenishable system is effective against all types of radiation particles.**

*Ames Research Center, Moffett Field, California*

Single-wall carbon nanotubes (SWCNTs) coated with a hydrogen-rich, electrically conducting polymer such as polyethylene, receive and dissipate a portion of incoming radiation pulse energy to electrical signals that are transmitted along the CNT axes, and are received at energy-dissipating terminals.

In this innovation, an array of highly aligned nanowires is grown using a strong electric field or another suitable orientation procedure. Polyethyl-

ene (PE), polymethylmethacrylate (PMMA), or other electrically conducting polymer is spin-coated onto the SWCNTs with an average thickness of a few hundred nanometers to a few tenths of micrometers to form a PE/SWCNT composite. Alternatively, the polymer is spin-coated onto the nanowire array or an anodized alumina membrane (AAM) to form a PE/metal core shell structure, or PE can be electropolymerized using the

SWCNTs or the metal nanowires as an electrode to form a PE/SWCNT core shell structure.

The core shell structures can be extruded as anisotropic fibers. A monomer can be polymerized in the presence of SWCNTs to form highly cross-linked PE/SWCNT films. Alternatively, Pb colloid solution can be impregnated into a three-dimensional PE/SWCNT nanostructure to form a PW/SWCNT/Pb composite structure. A face-centered cubic

(FCC) arrangement provides up to 12 interconnection channels connected to each core, with transverse channel dimensions up to 20 nm, with adequate mechanical compressive strength, and with an associated electrical conductivity of around 3 Seimens/cm for currents ranging from 0.01 to 10 mA. This three-dimensional nanostructure is used as a host material to house appropriate radiation shielding material such as hydrogen-rich polymer/CNT structures, metal nanoparticles, and nanowires.

Thicknesses of this material required to attenuate 10 percent, 50 percent, and

90 percent of an incident beam (gamma, X-ray, ultraviolet, neutron, proton, and electron) at energies in the range of 0–440 MeV are being determined, for example, by measuring fluence rate reduction.

For example, a radiation field arrives first at an exposed surface of the innovation and produces an associated first electric field within the metal-like fingers of the three-dimensional nanostructure. This field is intensified near the exposed tips of the fingers, and this intensified field generates an intensified second electric field near

the adjacent exposed tips of the coated CNSs. This generates an associated electrical current in the CNSs, and the associated electropolymer coating. The current is received by the second substrate transport component and is transported to the dissipation mechanism located contiguously to the second substrate.

*This work was done by Chris McKay of Ames Research Center and Bin Chen of LC Tech (a co-op agreement with NASA). Further information is contained in a TSP (see page 1). ARC-15983-1*



## Nano Sponges for Drug Delivery and Medicinal Applications

**These non-toxic nano sponges are a means to deliver a drug or payload to cells in an extended-release fashion.**

*Lyndon B. Johnson Space Center, Houston, Texas*

This invention is a means of delivering a drug, or payload, to cells using non-covalent associations of the payload with nano-engineered scaffolds; specifically, functionalized single-walled carbon nanotubes (SWNTs) and their derivatives where the payload is effectively sequestered by the nanotube's addends and then delivered to the site (often interior of a cell) of interest.

Polyethylene glycol (PEG) and other water-soluble organic molecules have been shown to greatly enhance the solubility of SWNTs in water. PEG groups and other water-solubilizing addends can act to sequester ("sponge") molecules and deliver them into cells. Using PEG that, when attached to the SWNTs, the SWNT/PEG matrix will enter cells has been demonstrated. This was visualized by the addition of fluorescein isothiocyanate (FITC) to the SWNT/PEG matrix. Control studies showed that both FITC alone and FITC/PEG did not enter the cells. These observations suggest that the FITC is highly associated with the SWNT/PEG matrix that brings the FITC into the cells, allowing visualization of SWNTs in cells.

The FITC is not covalently attached, because extended dialysis in hot DMF will remove all fluorescence quickly (one week). However, prolonged dialysis in water (1–2 months) will only slowly diminish the fluorescence. This demonstrates that the SWNT/PEG matrix solubilizes the FITC by sequestering it from

the surrounding water and into the more solubilizing organic environment of the SWNT/PEG matrix of this type. This can be extended for the sequestering of other molecules such as drugs with PEG and other surfactants.

For example, it was shown that the water-insoluble anti-cancer drug paclitaxel (Taxol) could be effectively dissolved in water via the sponging action of the SWNT/PEG matrix in solution. When one milligram of paclitaxel dissolved in 70  $\mu$ L of ethanol is added into 1 mL of water, the drug will immediately precipitate out of solution once in contact with the water. However, when the same amount of dissolved paclitaxel is added into 1 mL of the SWNT/PEG matrix solution in water, no paclitaxel precipitates out of solution. This is attributed to the paclitaxel being sequestered from the water and into the more favorable SWNT/PEG matrix. In this way, water-soluble solutions of paclitaxel were made.

In preliminary studies, using the well established MIT assay, the "sponged" paclitaxel was shown to have comparable cell-killing ability as the cremophor-stabilized Taxol used in current clinical cancer treatment. The SWNT/PEG matrix, which was shown to be non-toxic to cells, could be an effective alternative for the drug delivery vehicle cremophor, which is known to cause debilitating side effects in some cancer patients. The nano sponge should behave similarly in

the solubilization of other molecules with limited or no water solubility. In addition, the material also serves as a protective barrier, sheltering the drug or payload from premature destruction within the body before it reaches the final destination of the cell. Moreover, one could simply add the functionalized SWNTs into a solution of the drug or fluorescent tag of choice, incubate in order to have the SWNT/PEG matrix sequester the drug or tag, and then administer the entire solution for delivery.

*This work was done by James M. Tour, Rebecca Lucente-Schultz, Ashley Leonard, Dmitry V. Kosynkin, Brandi Katherine Price, and Jared L. Hudson of Rice University; and Jodie L. Conyers Jr., Valerie C. Moore, S. Ward Casscells, Jeffrey N. Myers, Zvonimir L. Milas, Luka Milas, and Kathy A. Mason of the University of Texas for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Lydia A. Tkachenko, Patent Manager  
Rice University  
Office of Technology Transfer-MS 705  
P.O. Box 1892  
Houston, TX 77251-1892  
Phone No.: (713) 348-6188  
E-mail: techtran@rice.edu*

*Refer to MSC-24504-1, volume and number of this NASA Tech Briefs issue, and the page number.*

## Molecular Technique to Understand Deep Microbial Diversity

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Current sequencing-based and DNA microarray techniques to study microbial diversity are based on an initial PCR (polymerase chain reaction) amplification step. However, a number of factors are known to bias PCR amplification and jeopardize the true repre-

sentation of bacterial diversity. PCR amplification of the minor template appears to be suppressed by the exponential amplification of the more abundant template. It is widely acknowledged among environmental molecular microbiologists that genetic biosignatures

identified from an environment only represent the most dominant populations. The technological bottleneck has overlooked the presence of the less abundant "minority population," and underestimated their role in the ecosystem maintenance.

To generate PCR amplicons for subsequent diversity analysis, bacterial 16S rRNA genes are amplified by PCR using universal primers. Two distinct PCR regimes are employed in parallel: one using normal and the other using biotin-labeled universal primers. PCR products obtained with biotin-labeled primers are mixed with streptavidin-labeled mag-

netic beads and selectively captured in the presence of a magnetic field. Less-abundant DNA templates that fail to amplify in this first round of PCR amplification are subjected to a second round of PCR using normal universal primers. These PCR products are then subjected to downstream diversity analyses such as conventional cloning and sequencing. A

second round of PCR amplified the minority population and completed the deep diversity picture of the environmental sample.

*This work was done by Parag A. Vaishampayan and Kasthuri J. Venkateswaran of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47993*

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## **Methods and Compositions Based on Culturing Microorganisms in Low Sedimental Fluid Shear Conditions**

*Lyndon B. Johnson Space Center, Houston, Texas*

The benefits of applying a low sedimental fluid shear environment to manipulate microorganisms were examined. Microorganisms obtained from a low sedimental fluid shear culture, which exhibit modified phenotypic and molecular genetic characteristics, are useful for the development of novel and improved diagnostics, therapeutics, vaccines, and bio-industrial products. Furthermore, application of low sedimental fluid conditions to microorganisms permits identification of molecules uni-

quely expressed under these conditions, providing a basis for the design of new therapeutic targets.

*This work was done by C. Mark Ott of Johnson Space Center; Cheryl A. Nickerson, James W. Wilson, and Shameema Sarker of Arizona State University; Eric A. Nauman of Purdue University; Michael J. Schurr of the University of Colorado Health Science Center; and Mayra A. Nelman-Gonzalez of Wyle Laboratories. For further information, see <http://www.wipo.int/pctdb/en/wo.jsp?WO=2009036036>*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Arizona State University  
Center for Infectious Diseases and Vaccinology  
P.O. Box 875401  
Tempe, AZ 85587-5401  
Phone No. (480) 727-7520  
E-mail: [cheryl.nickerson@asu.edu](mailto:cheryl.nickerson@asu.edu)*

*Refer to MSC-24584-1, volume and number of this NASA Tech Briefs issue, and the page number.*



## Secure Peer-to-Peer Networks for Scientific Information Sharing

**This technique combines advantages of social networks with peer-to-peer file sharing.**

*Goddard Space Flight Center, Greenbelt, Maryland*

The most common means of remote scientific collaboration today includes the trio of e-mail for electronic communication, FTP for file sharing, and personalized Web sites for dissemination of papers and research results. With the growth of broadband Internet, there has been a desire to share large files (movies, files, scientific data files) over the Internet. E-mail has limits on the size of files that can be attached and transmitted. FTP is often used to share large files, but this requires the user to set up an FTP site for which it is hard to set group privileges, it is not straightforward for everyone, and the content is not searchable.

Peer-to-peer technology (P2P), which has been overwhelmingly successful in

popular content distribution, is the basis for development of a scientific laboratory called Scientific Peer Network (SciPerNet). This technology combines social networking with P2P file sharing. SciPerNet will be a standalone application, written in Java and Swing, thus insuring portability to a number of different platforms. Some of the features include user authentication, search capability, seamless integration with a data center, the ability to create groups and social networks, and on-line chat.

In contrast to P2P networks such as Gnutella, Bit Torrent, and others, SciPerNet incorporates three design elements that are critical to application of P2P for scientific purposes:

- User authentication,
- Data integrity validation,
- Reliable searching

SciPerNet also provides a complementary solution to virtual observatories by enabling distributed collaboration and sharing of downloaded and/or processed data among scientists. This will, in turn, increase scientific returns from NASA missions. As such, SciPerNet can serve a two-fold purpose for NASA: a cost-savings software as well as a productivity tool for scientists working with data from NASA missions.

*This work was done by Homa Karimabadi of SciberQuest, Inc. for Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15396-1*

## Multiplexer/Demultiplexer Loading Tool (MDMLT)

**This is a readily modifiable tool designed for any facility requiring the loading of computers.**

*Lyndon B. Johnson Space Center, Houston, Texas*

The purpose of the MDMLT is to improve the reliability and speed of loading multiplexers/demultiplexers (MDMs) in the Software Development and Integration Laboratory (SDIL) by automating the configuration management (CM) of the loads in the MDMs, automating the loading procedure, and providing the capability to load multiple or all MDMs concurrently. This loading may be accomplished in parallel, or single MDMs (remote). The MDMLT is a Web-based tool that is capable of loading the entire International Space Station (ISS) MDM configuration in parallel. It is able to load Flight Equivalent Units (FEUs), enhanced, standard, and prototype MDMs as well as both EEPROM (Electrically Erasable Programmable Read-Only Memory) and SSMMU (Solid State Mass Memory Unit) (MASS Memory). This software has extensive configuration management to track loading history, and the performance improvement means of loading the entire ISS MDM configuration of 49 MDMs

in approximately 30 minutes, as opposed to 36 hours, which is what it took previously utilizing the flight method of S-Band uplink. The laptop version recently added to the MDMLT suite allows remote lab loading with the CM of information entered into a common database when it is reconnected to the network. This allows the program to reconfigure the test rigs quickly between shifts, allowing the lab to support a variety of onboard configurations during a single day, based on upcoming or current missions.

The MDMLT Computer Software Configuration Item (CSCI) supports a Web-based command and control interface to the user. An interface to the SDIL File Transfer Protocol (FTP) server is supported to import Integrated Flight Loads (IFLs) and Internal Product Release Notes (IPRNs) into the database. An interface to the Monitor and Control System (MCS) is supported to control the power state, and to enable or disable the debug port of the MDMs to be loaded. Two direct interfaces

to the MDM are supported: a serial interface (debug port) to receive MDM memory dump data and the calculated checksum, and the Small Computer System Interface (SCSI) to transfer load files to MDMs with hard disks. File transfer from the MDM Loading Tool to EEPROM within the MDM is performed via the MIL-STD-1553 bus, making use of the Real-Time Input/Output Processors (RTIOP) when using the rig-based MDMLT, and via a bus box when using the laptop MDMLT. The bus box is a cost-effective alternative to PC-1553 cards for the laptop.

It is noted that this system can be modified and adapted to any avionics laboratory for spacecraft computer loading, ship avionics, or aircraft avionics where multiple configurations and strong configuration management of software/firmware loads are required.

*This work was done by Lenox Allen Brewer of Johnson Space Center; Elizabeth Hale and Robert Martella of Cimarron; and Ryan Gyorf of The Boeing Co. Further information is contained in a TSP (see page 1). MSC-24480-1*

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## ➤ High-Rate Data-Capture for an Airborne Lidar System

**Potential applications are in laser altimeter systems, mass spectroscopy, x-ray radiometry imaging, and high-background-rate ranging lidar.**

*Goddard Space Flight Center, Greenbelt, Maryland*

A high-rate data system was required to capture the data for an airborne lidar system. A data system was developed that achieved up to 22 million (64-bit) events per second sustained data rate (1408 million bits per second), as well as short bursts (<4 s) at higher rates. All hardware used for the system was off the shelf, but carefully selected to achieve these rates. The system was used to capture laser fire, single-photon detection, and GPS data for the Slope Imaging Multi-polarization Photo-counting Lidar (SIMPL). However, the system has applications for other laser altimeter systems (waveform-recording), mass spectroscopy, x-ray radiometry imaging, high-background-rate ranging lidar, and other similar areas where very high-speed data capture is needed.

The data capture software was used for the SIMPL instrument that employs a micropulse, single-photon ranging measurement approach and has 16 data

channels. The detected single photons are from two sources — those reflected from the target and solar background photons. The instrument is non-gated, so background photons are acquired for a range window of 13 km and can comprise many times the number of target photons. The highest background rate occurs when the atmosphere is clear, the Sun is high, and the target is a highly reflective surface such as snow. Under these conditions, the total data rate for the 16 channels combined is expected to be approximately 22 million events per second.

For each photon detection event, the data capture software reads the relative time of receipt, with respect to a one-per-second absolute time pulse from a GPS receiver, from an event timer card with 0.1-ns precision, and records that information to a RAID (Redundant Array of Independent Disks) storage device. The relative time of laser pulse firings must also be read

and recorded with the same precision. Each of the four event timer cards handles the throughput from four of the channels. For each detection event, a flag is recorded that indicates the source channel. To accommodate the expected maximum count rate and also handle the other extreme of very low rates occurring during nighttime operations, the software requests a set amount of data from each of the event timer cards and buffers the data. The software notes if any of the cards did not return all the data requested and then accommodates that lower rate. The data is buffered to minimize the I/O overhead of writing the data to storage. Care was taken to optimize the reads from the cards, the speed of the I/O bus, and RAID configuration.

*This work was done by Susan Valett, Edward Hicks, Philip Dabney, and David Harding of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16018-1*

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## ➤ Wavefront Sensing Analysis of Grazing Incidence Optical Systems

**As a metrology tool, this method allows integration of high-angular-resolution optics without the use of normal incidence interferometry.**

*Goddard Space Flight Center, Greenbelt, Maryland*

Wavefront sensing is a process by which optical system errors are deduced from the aberrations in the image of an ideal source. The method has been used successfully in near-normal incidence systems, but not for grazing incidence systems. This innovation highlights the ability to examine out-of-focus images from grazing incidence telescopes (typically operating in the x-ray wavelengths, but integrated using optical wavelengths) and determine the lower-order deformations. This is important because as a metrology tool, this method would allow the integration of high angular resolution optics without the use of normal incidence interferometry, which requires direct access to the front surface of each mirror.

Measuring the surface figure of mirror segments in a highly nested x-ray telescope mirror assembly is difficult due to the tight packing of elements and blockage of all but the innermost elements to normal incidence light. While this can be done on an individual basis in a metrology mount, once the element is installed and permanently bonded into the assembly, it is impossible to verify the figure of each element and ensure that the necessary imaging quality will be maintained. By examining on-axis images of an ideal point source, one can gauge the low-order figure errors of individual elements, even when integrated into an assembly. This technique is known as wavefront sensing (WFS).

By shining collimated light down the optical axis of the telescope and looking

at out-of-focus images, the blur due to low-order figure errors of individual elements can be seen, and the figure error necessary to produce that blur can be calculated. The method avoids the problem of requiring normal incidence access to the surface of each mirror segment. Mirror figure errors span a wide range of spatial frequencies, from the lowest-order “bending” to the highest-order “micro-roughness.” While all of these can be measured in normal incidence, only the lowest-order contributors can be determined through this WFS technique.

During integration, typically only the low-order shape changes. The stress introduced does not affect the higher-order ripple or roughness, so one can use the measurements done in normal

incidence to characterize the mirror in the mid- and high-frequency domains, and WFS measurements for the low-frequency domain.

By analyzing multiple out-of-focus images at different positions, the path of each photon can be determined, and the figure error necessary to generate that array of photon paths can be deduced. The method is applicable to any wavelength being examined, though the range of spatial periods that

can be examined depends on what wavelength of light is being imaged, due to diffraction blurring out the focused image.

The innovation is unique in that it determines physical surface errors using a method that requires neither normal incidence access nor contact of the optical surface. The primary advantage of the technique is the ability to probe surface figure errors when the mirror is in a system that denies ac-

cess to the front surface of the mirror, such as during x-ray testing (requiring the mirror to be in a vacuum chamber) or after it has been integrated into a highly nested structure. This software is capable of determining figure errors at the sub-micrometer level for up to 4th order errors.

*This work was done by Scott Rohrbach and Timo Saha of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15926-1*

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## Foam-on-Tile Damage Model

*Lyndon B. Johnson Space Center, Houston, Texas*

An impact model was developed to predict how three specific foam types would damage the Space Shuttle Orbiter insulating tiles. The inputs needed for the model are the foam type, the foam mass, the foam impact velocity, the foam impact incident angle, the type being impacted, and whether the tile is new or aged (has flown at least one mission). The model will determine if the foam impact will cause damage to the tile. If it can cause damage, the model will output the damage cavity dimensions

(length, depth, entry angle, exit angle, and sidewall angles).

It makes the calculations as soon as the inputs are entered (<1 second). The model allows for the rapid calculation of numerous scenarios in a short time. The model was developed from engineering principles coupled with significant impact testing (over 800 foam impact tests). This model is applicable to masses ranging from 0.0002 up to 0.4 pound (0.09 up to 181 g).

A prior tool performed a similar function, but was limited to the assessment of a small range of masses and did not have the large test database for verification. In addition, the prior model did not provide outputs of the cavity damage length, entry angle, exit angle, or sidewall angles.

*This work was done by Michael Koharchik, Lindsay Murphy, and Paul Parker of The Boeing Company for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24913-1*





### **Instrument Package Manipulation Through the Generation and Use of an Attenuated-Fluent Gas Fold**

This document discusses a technique that provides a means for suspending large, awkward loads, instrument packages, components, and machinery in a stable, controlled, and precise manner. In the baseplate of the test machine, a pattern of grooves and ports is installed that when pressurized generates an attenuated-fluent gas fold providing a low-cost, near-zero-coefficient-of-friction lubrication boundary layer that supports the object evenly, and in a predictable manner. Package movement control requires minimal force.

Aids to repeatable travel and positional accuracy can be added via the addition of simple guide bars and stops to the floor or object being moved. This allows easily regulated three-axis motions. Loads of extreme weight and size can be moved and guided by a single person, or by automated means, using minimal force. Upon removal of the attenuated-fluent gas fold, the object returns to a stable resting position without impact forces affecting the object.

*This work was done by Daniel P. Breen of ASRC Aerospace 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-18739-1.*

### **Multicolor Detectors for Ultrasensitive Long-Wave Imaging Cameras**

A document describes a zeptobolometer for ultrasensitive, long-wavelength sensors. GSFC is developing pixels based on the zeptobolometer design that sense three THz wavelengths simultaneously.

Two innovations are described in the document: (1) a quasiparticle (QO) filter arrangement that enables a compact multicolor spectrum at the focal plane, and

(2) a THz antenna readout by up to three bolometers. The innovations enable high efficiency by greatly reducing high, frequency-dependent microstrip losses, and pixel compactness by eliminating the need for bulky filters in the focal plane.

The zeptobolometer is a small TES bolometer, on the scale of a few microns, which can be readily coupled through an impedance-matching resistor to a metal or dielectric antenna. The bolometer is voltage-biased in its superconducting transition, allowing the use of superconducting RF multiplexers to read out large arrays. The antenna is geometrically tapped at three locations so as to efficiently couple radiation of three distinct wavelengths to the individual TESs. The transition edge hot electrons in metals offer a simple, compact arrangement for antenna readout, which can be crucial in the THz where line losses at high frequencies can be substantial. A metallic grill filter acts as a high-pass filter and directs the low-frequency components to a location where they will be absorbed. The absorption spectrum shows that three well-separated THz bands are feasible. The filters can be made from high-purity dielectrics such as float zone silicon or sapphire.

*This work was done by Ari Brown, Dominic Benford, James Chervenak, and Edward Wollack of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15672-1*

### **Lunar Reconnaissance Orbiter (LRO) Command and Data Handling Flight Electronics Subsystem**

A document describes a high-performance, modular, and state-of-the-art Command and Data Handling (C&DH) system developed for use on the Lunar Reconnaissance Orbiter (LRO) mission. This system implements a complete hardware C&DH subsystem in a single chassis enclosure that includes a processor card, 48 Gbytes of solid-state recorder memory, data buses including MIL-STD-1553B, custom RS-422, SpaceWire, analog collection, switched power services, and interfaces to the Ka-Band and S-Band RF communications systems.

The C&DH team capitalized on extensive experience with hardware and software with PCI bus design, SpaceWire networking, Actel FPGA design, digital flight design techniques, and the use of VxWorks for the real-time operating system. The resulting hardware architecture was implemented to meet the LRO mission requirements.

The C&DH comprises an enclosure, a backplane, a low-voltage power converter, a single-board computer, a communications interface board, four data storage boards, a housekeeping and digital input/output board, and an analog data acquisition board. The interfaces between the C&DH and the instruments and avionics are connected through a SpaceWire network, a MIL-STD-1553 bus, and a combination of synchronous and asynchronous serial data transfers over RS-422 and LVDS (low-voltage differential-signaling) electrical interfaces. The C&DH acts as the spacecraft data system with an instrument data manager providing all software and internal bus scheduling, ingestion of science data, distribution of commands, and performing science operations in real time.

*This work was done by Quang Nguyen, William Yuknis, Noosha Haghani, Scott Pursley, and Omar Haddad of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16100-1*

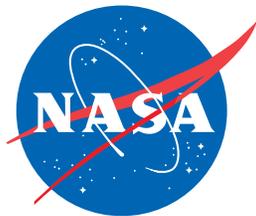
### **Electro-Optic Segment-Segment Sensors for Radio and Optical Telescopes**

A document discusses an electro-optic sensor that consists of a collimator, attached to one segment, and a quad diode, attached to an adjacent segment. Relative segment-segment motion causes the beam from the collimator to move across the quad diode, thus generating a measureable electric signal. This sensor type, which is relatively inexpensive, can be configured as an edge sensor, or as a remote segment-segment motion sensor.

*This work was done by Alex Abramovici of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47528*







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